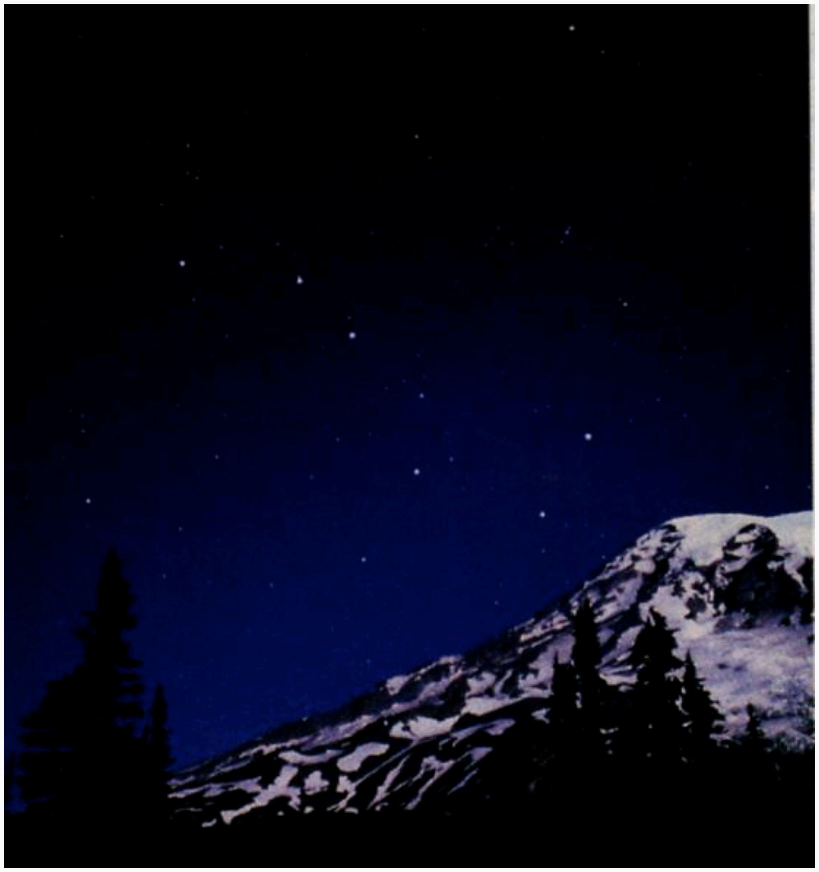
Chapter 1
Discovering the Night Sky



Donna Kubik
Fall, 2006

Chapter 1
Discovering the Night Sky

- Scales of the Universe
- Patterns of Stars
- Earthly cycles
- Eclipses

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- *Scales of the Universe*
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People-sized Spaces

- You
- Lecture Hall
- Faraday West
- NIU

- 5’9” = 1.75 m = 1.75×10^0 m
- 14 m = 1.4×10^1 m
- 80 m = 0.8×10^2 m
- 2000 m = 2.0×10^3 m

Map-Sized Spaces

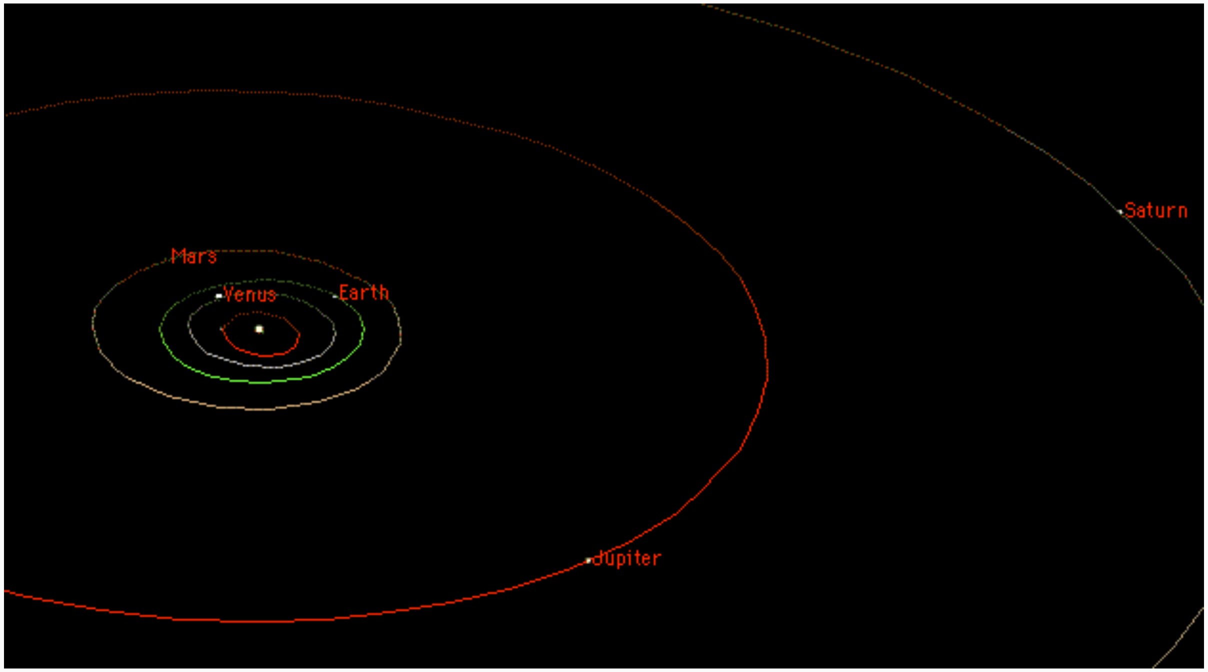
- DeKalb (city)
- DeKalb County
- Illinois
- United States

- 5000 m = 5 km = 5×10^3 m
- 30,000 m = 30 km = 3×10^4 m
- 400 km = 4×10^5 m
- 5000 km = 5×10^6 m

Space-Sized Spaces (Part 1)

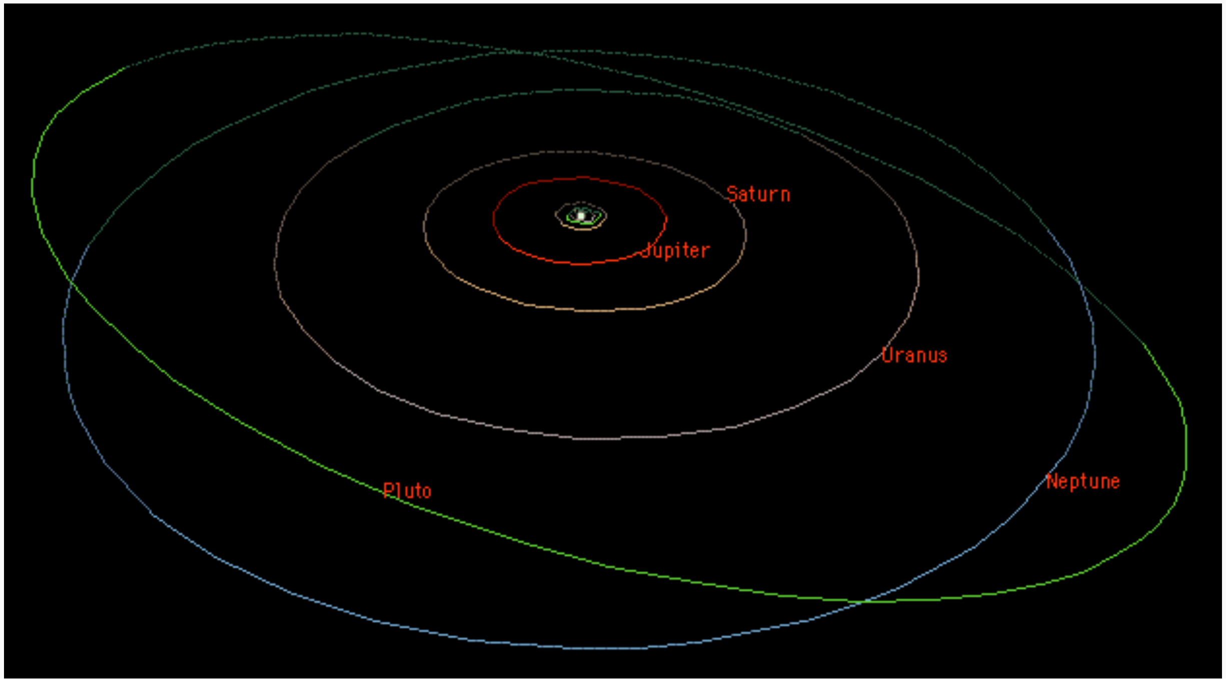
- Earth
- Earth and Moon
- Earth to the Sun

- 13,000 km = 1.3×10^7 m
- 384,000 km = 4×10^8 m
- 150,000,000 km = 1.5×10^{11} m
  This is 1 Astronomical Unit (1 AU)



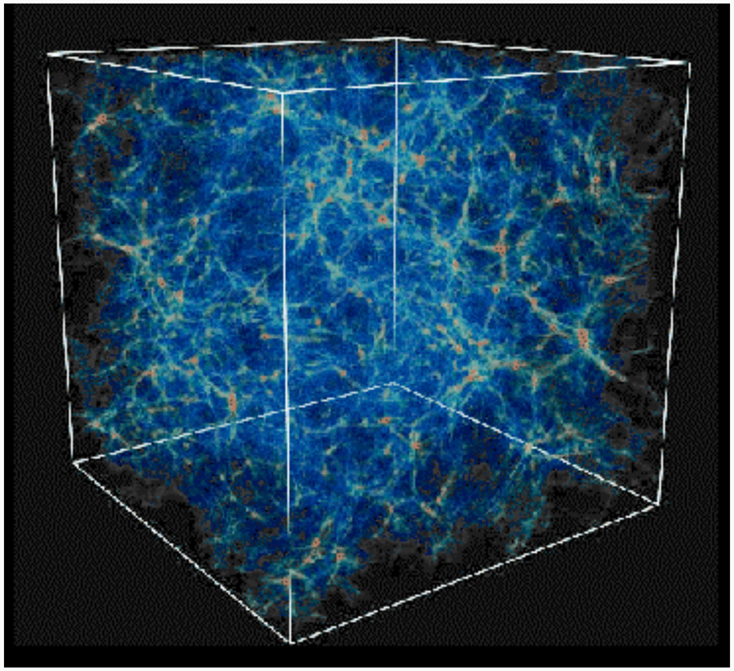
Space-Sized Spaces (Part 2)

- Earth to the Sun
- 1 AU = 1.5×10^{11} m
  8 light-minutes
- Solar System
- 500 AU = 0.8×10^{14} m
  3 light-days



Space-Sized Spaces (Part 3)

- Nearest Star
- 300,000 AU = 4 x 10^{16} m
  4.3 light years = 4.3 ly
- Milky Way
- 100,000 ly = 10^{21} m



Units often used in astronomy

- Astronomical Unit (AU)
- Light year (ly)
- Parsec (pc)

Astronomical Unit

- Used to discuss *distances across the Solar System*
- 1 astronomical unit (AU) = average distance from the Earth to the Sun
- 1 AU = 150,000,000 km = 1.5×10^8 km

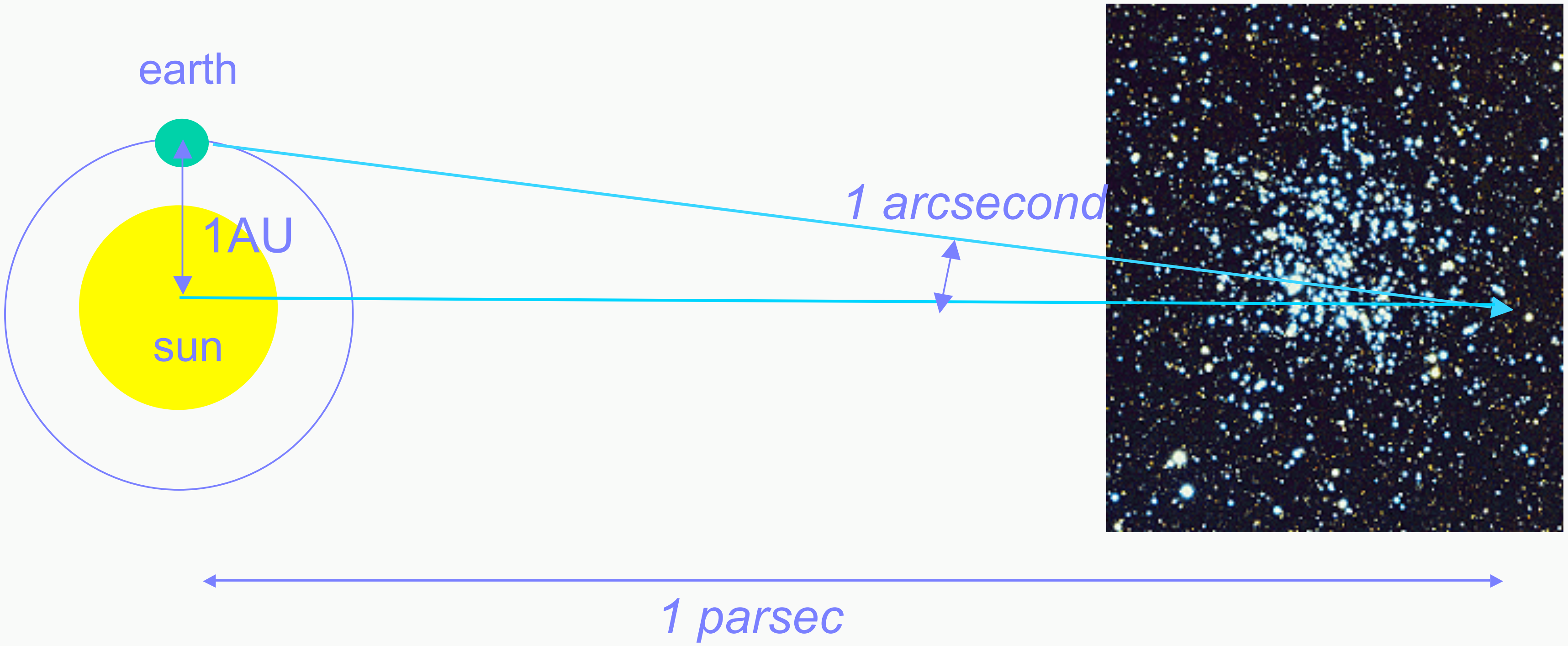
Light Year

- Used to discuss *distances to the stars*
- 1 light year (ly) = distance that light travels in one year
- 1 ly = 9.46×10^{12} km
- 1 ly = 63,000 AU
- Note: Remember light travels at ~3×10^{8} m/s

Distance to the closest star (Proxima Centauri) = 4.2 ly

Parsec

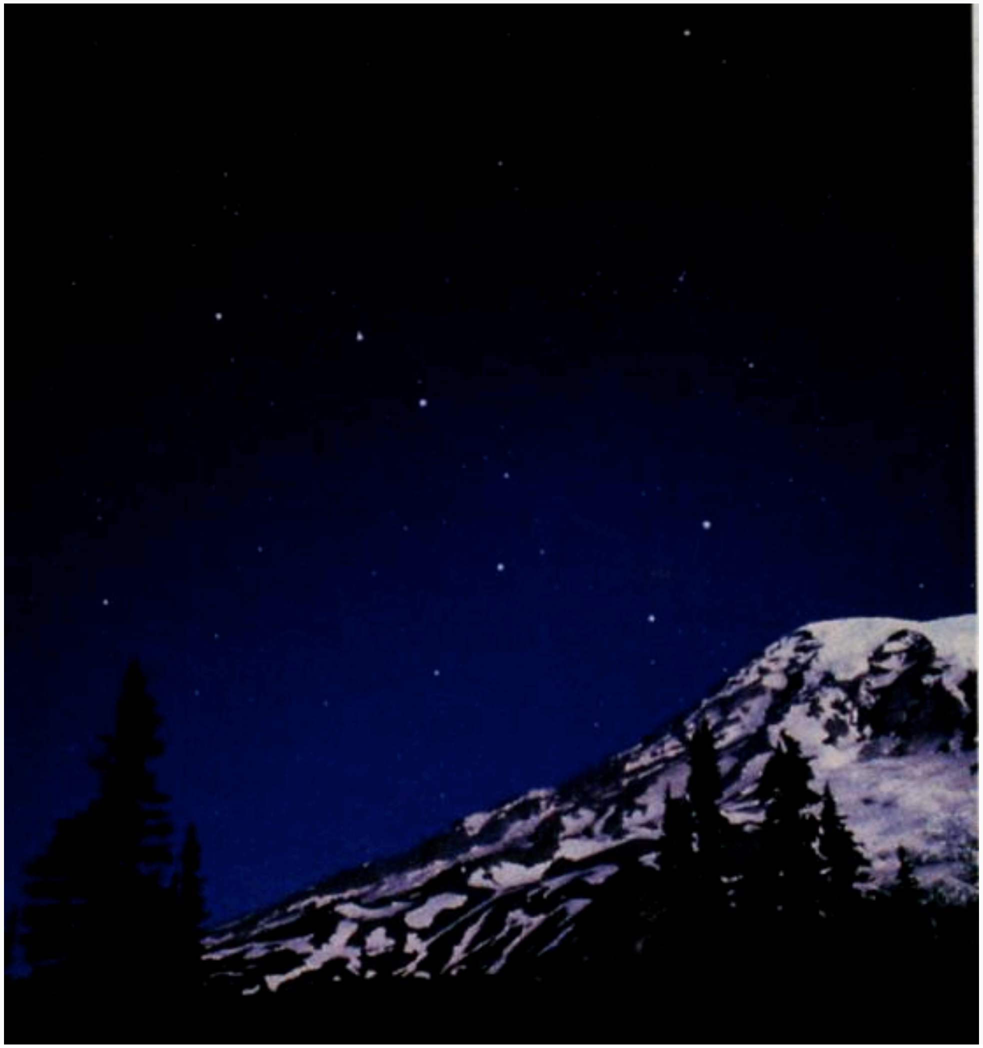
- Another unit used to discuss *distances to the stars*
- 1 parsec = 1 pc = 3.26 ly



Chapter 1
Discovering the Night Sky

- Scales of the Universe
- *Patterns of Stars*
- Earthly cycles
- Eclipses

Constellations

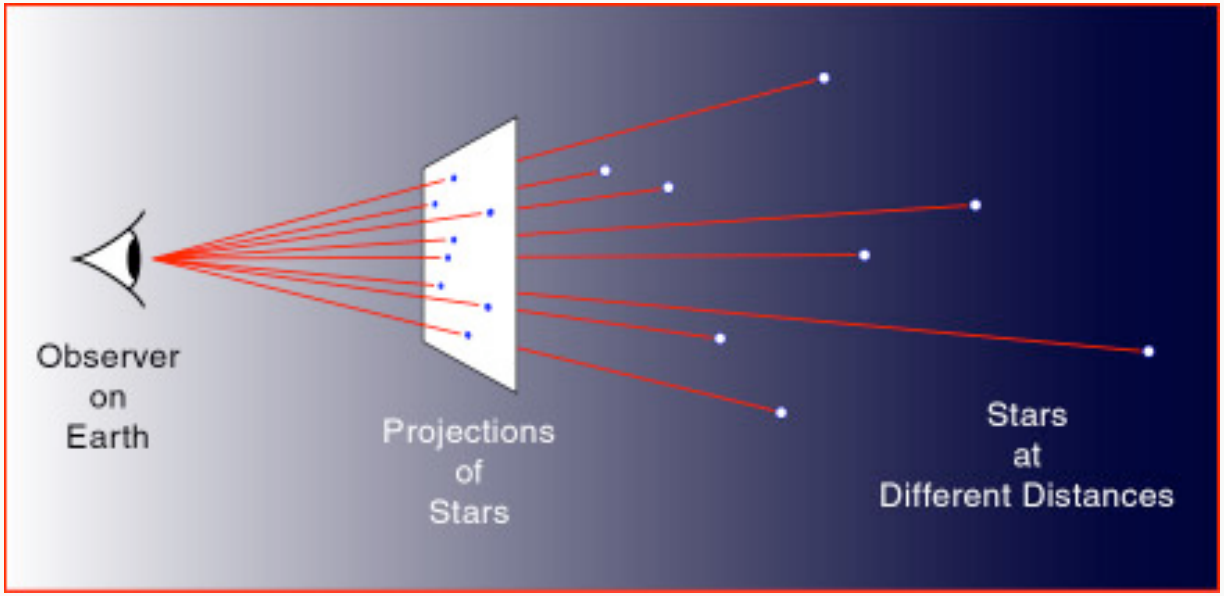


What are constellations?

- Constellations are patterns formed by bright stars
- The celestial sphere is divided into 88 unequal regions.
- These regions are what astronomers call constellations
- Astronomers use the term to describe an entire region of the sky and all the objects in that region

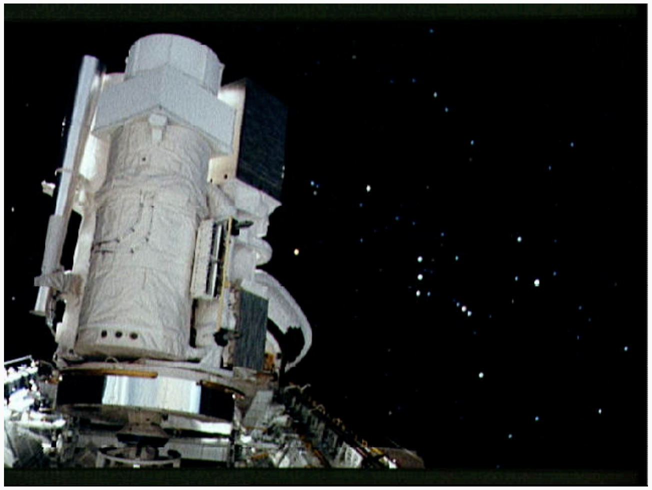
What are constellations?

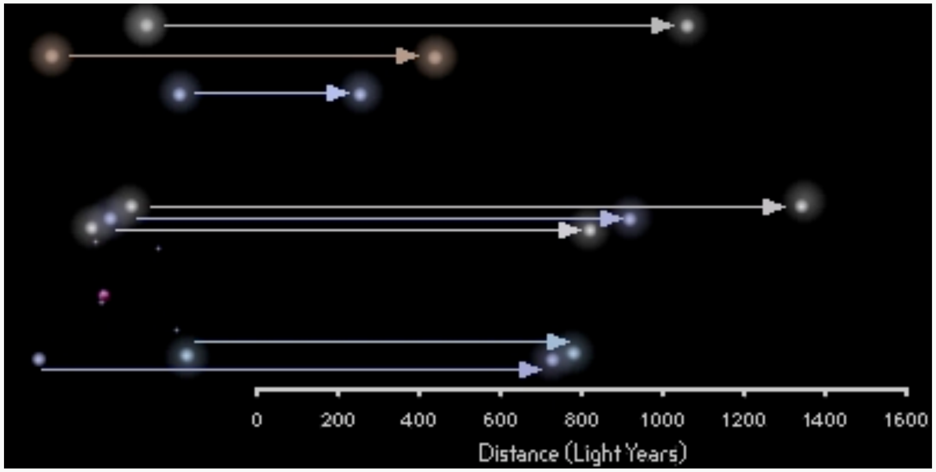
- We see the projected pattern of stars of varying distances



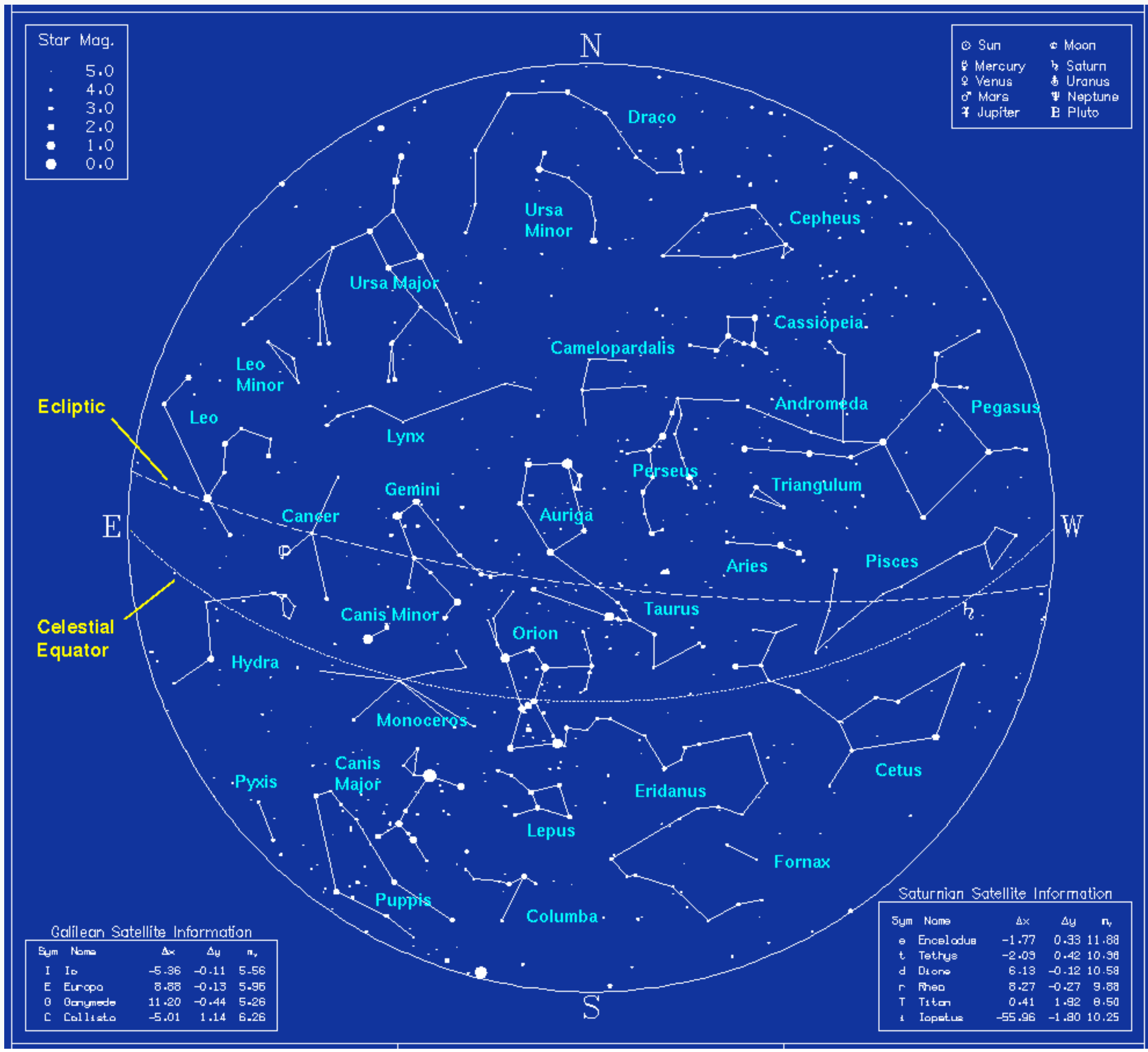
What are constellations?

- The stars in a constellation are not even near each other!





Map of the constellations



What are constellations?

- Historically, constellations were groupings of stars that were thought to outline the shape of something, usually with mythological significance.
- There are 88 recognized constellations, with their names tracing as far back as Mesopotamia, 5000 years ago.

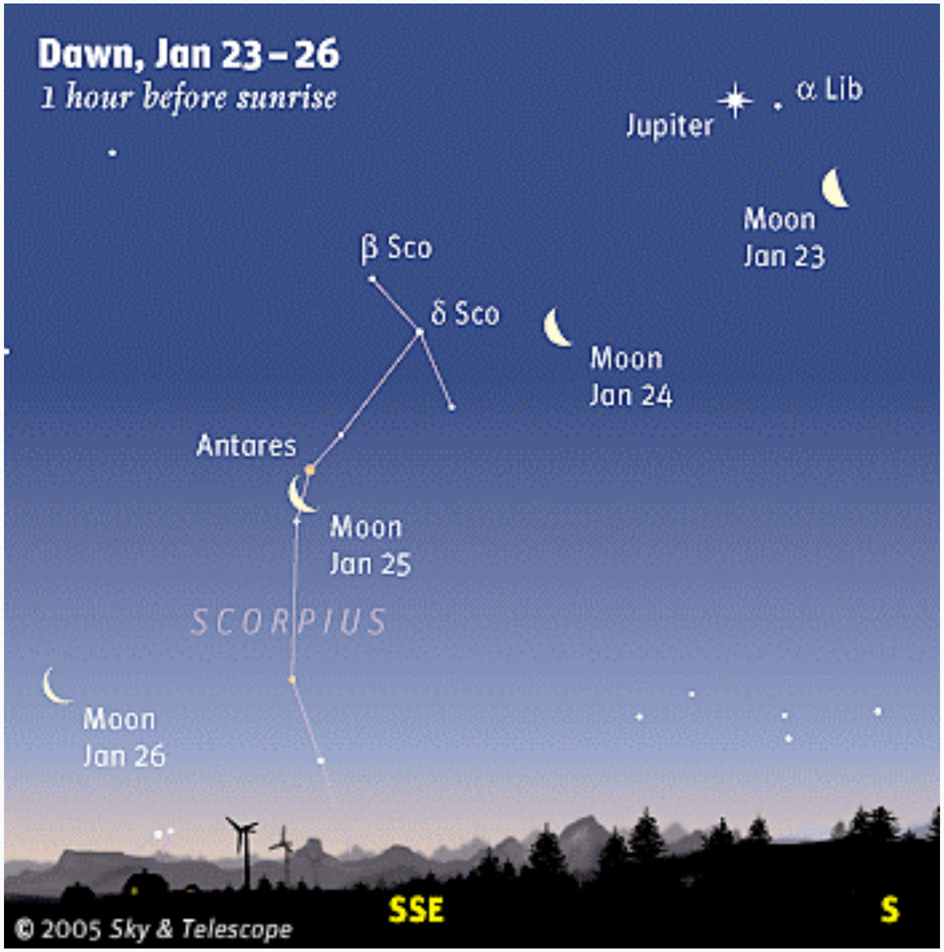
- In modern astronomy, the significance of constellations is no longer mythological, but practical: constellations define imaginary regions of the sky
- Just as the individual states each define an imaginary region of the United States.

What are constellations?

- Thus, to say that an object (planet, Moon, cluster, nebula, etc) is “in” the constellation Scorpius is to partially locate the planet on the celestial sphere, just as saying that Knoxville is in Tennessee is to partially locate the city on the surface of the Earth.
- Like states, modern constellations have irregular boundaries that have been agreed upon for various reasons, perhaps not always completely logical.

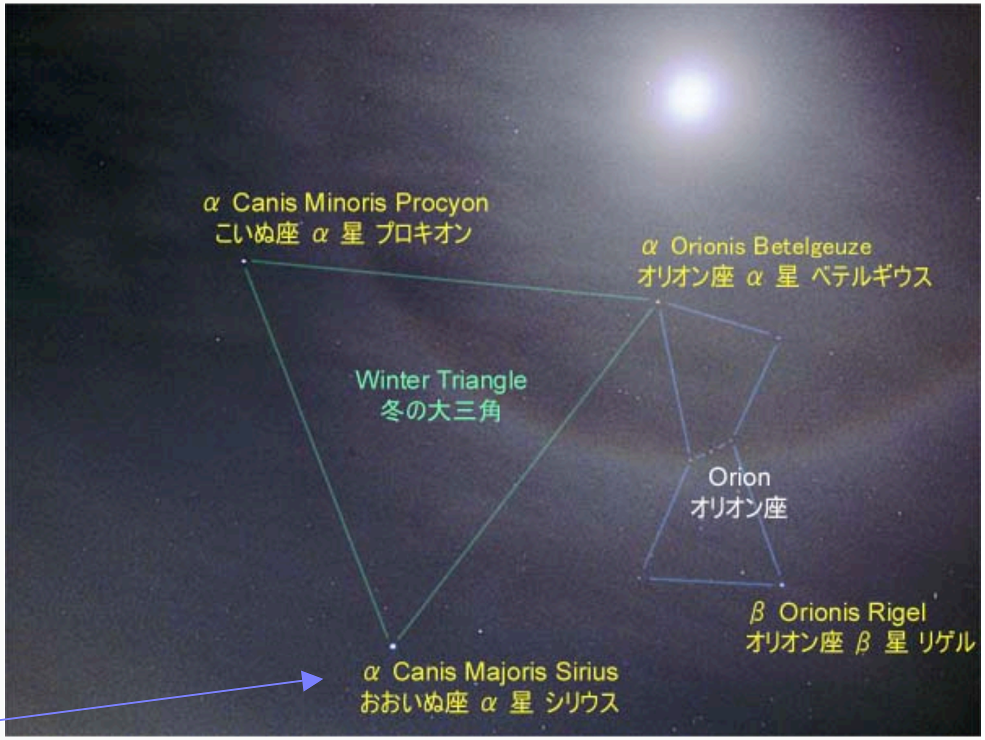
Using constellations as landmarks

- So you could say:
- "At dawn on Jan 25, the Moon will be in Scorpius."
- "Jupiter will be in Libra."



Star names

- Stars are generally designated by a Greek letter and the name of the constellation in which they reside.
- Usually α is the brightest star in the constellation, β is the second brightest, etc
- Sirius is the brightest star in the night sky

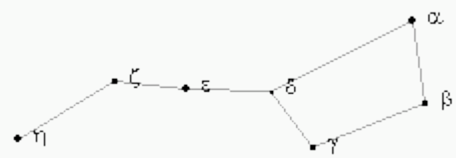


Constellations

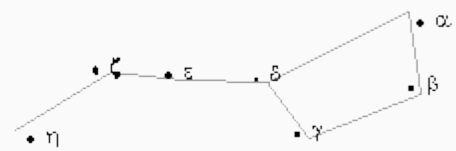
- Stars move on geologic timescales, so a constellation's pattern will change as is shown on the right for the Big Dipper

- The patterns are unchanging in ~10,000 year timescales

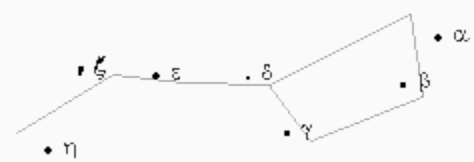
- BUT, their *position* in sky varies with season (as shown in next slide)



2000 A.D



50,000 A.D

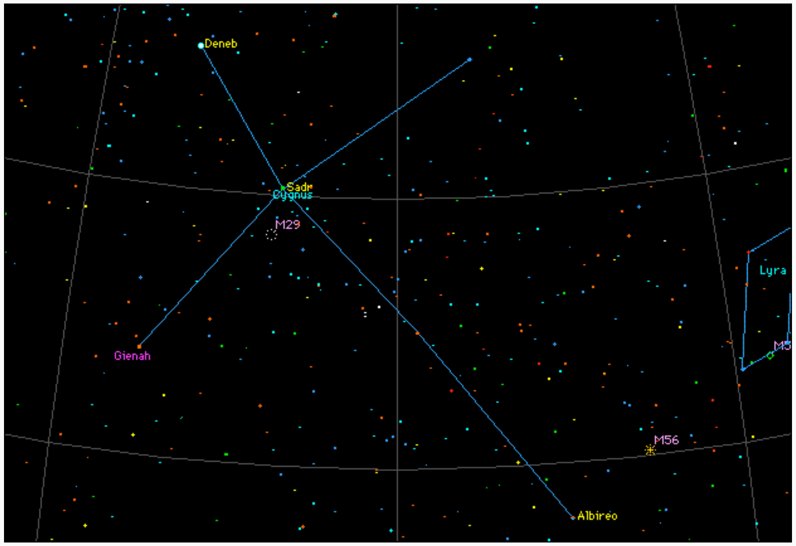


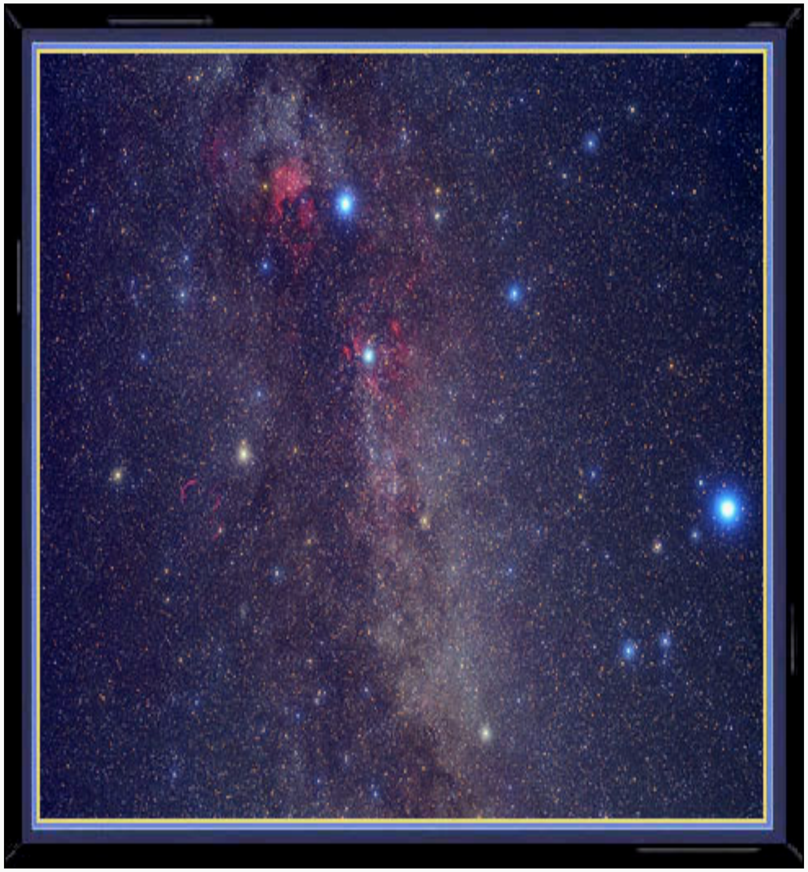
100,000 A.D

Different seasons, different constellations

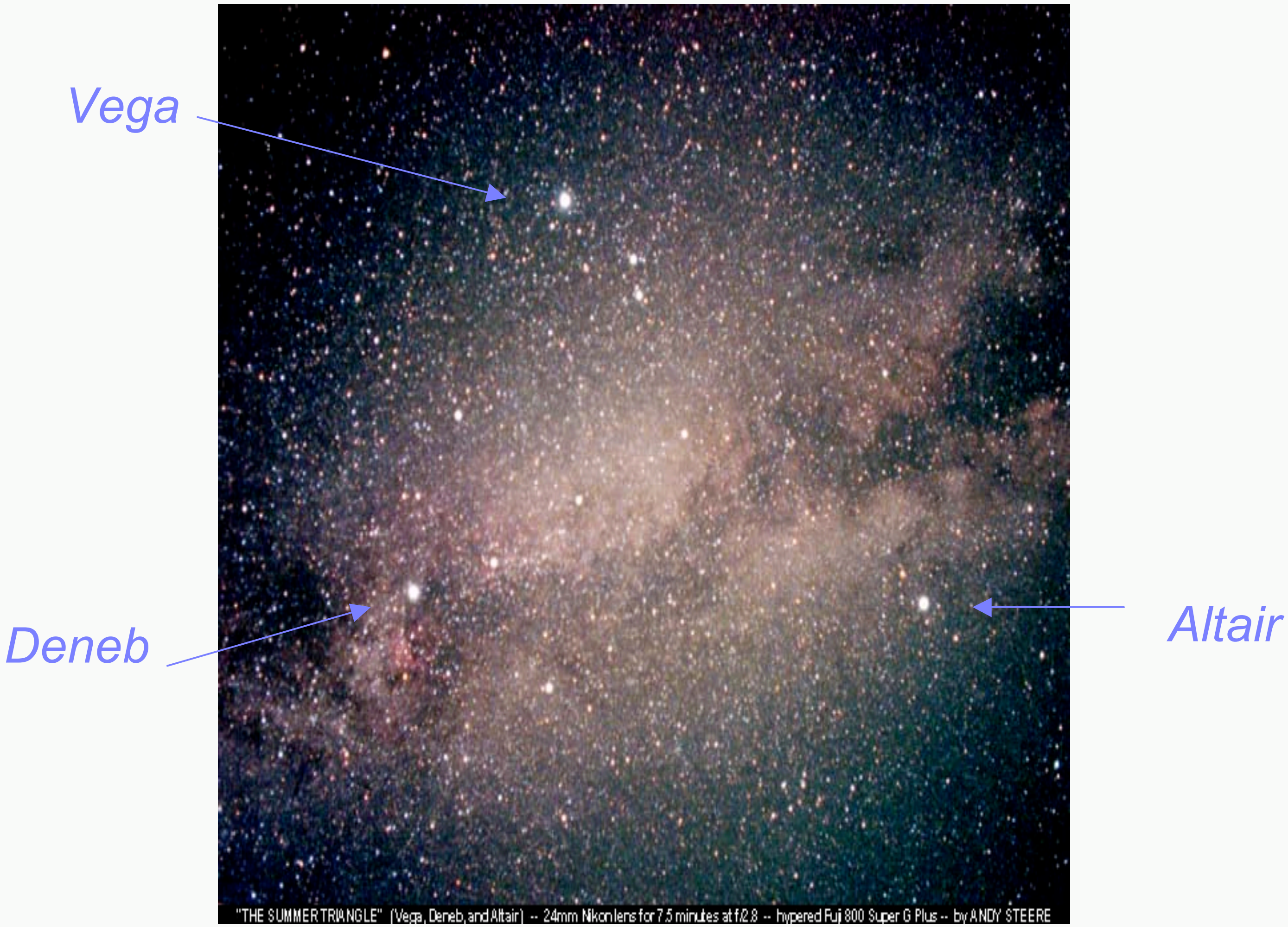
Summer constellations

- Cygnus (The Swan)

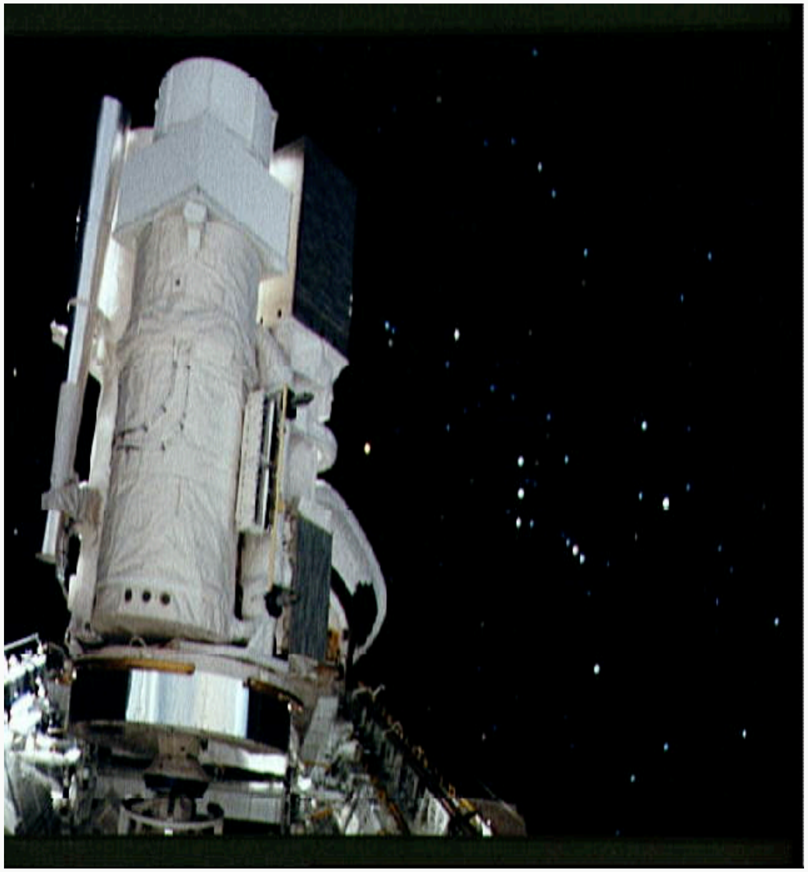




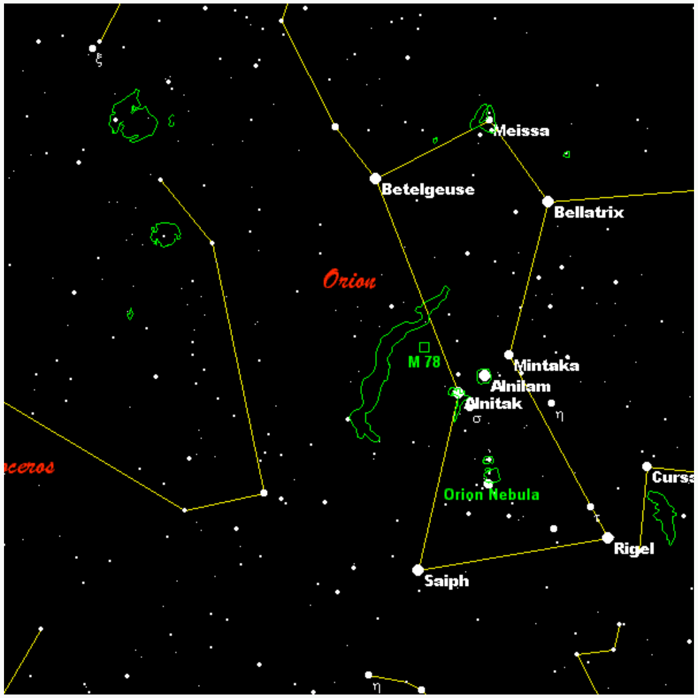
Summer triangle



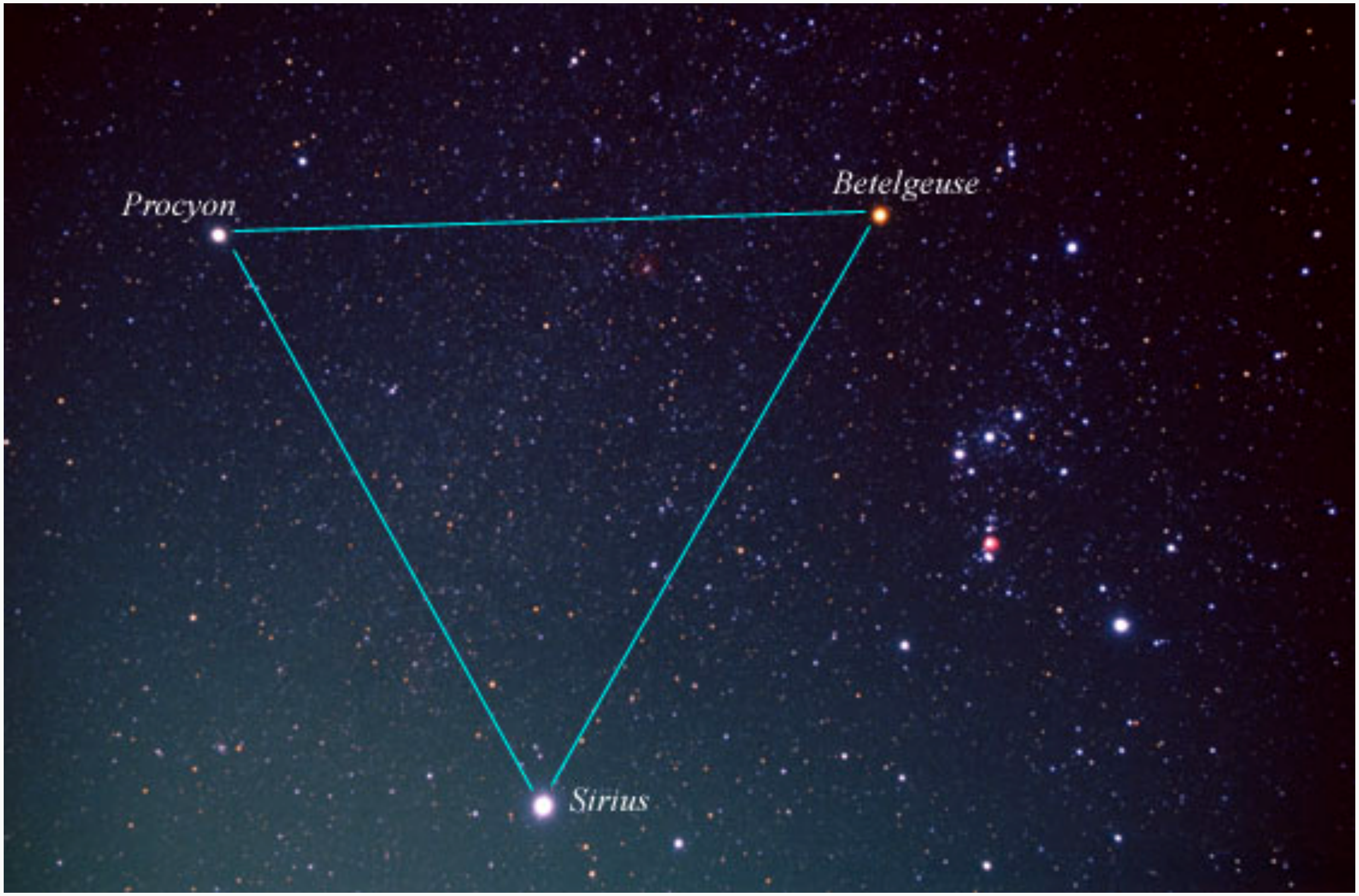
Winter Constellations



- Orion



Winter triangle



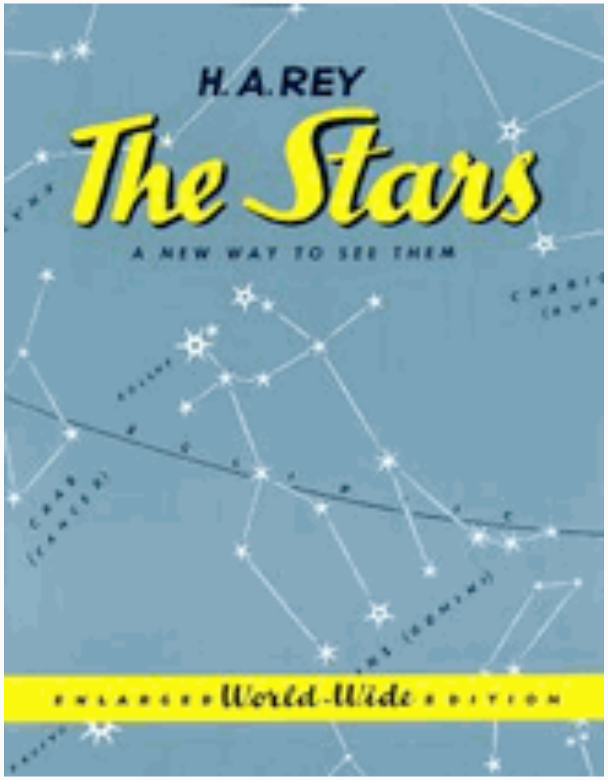
Constellations

- *"*The constellations have such intriguing names - somehow we expect the books to show us groups of stars in the shape of a Lion, a Whale, Twins, etc. But they show us nothing of the sort. This book serves to remedy the situation."
  - *~H A Rey*

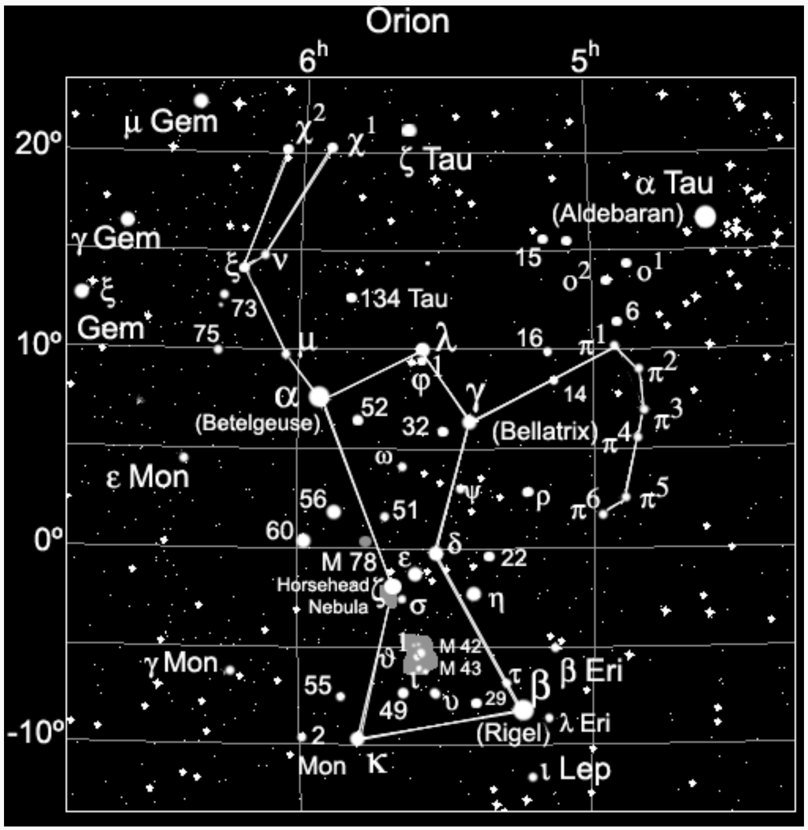
H. A. Rey

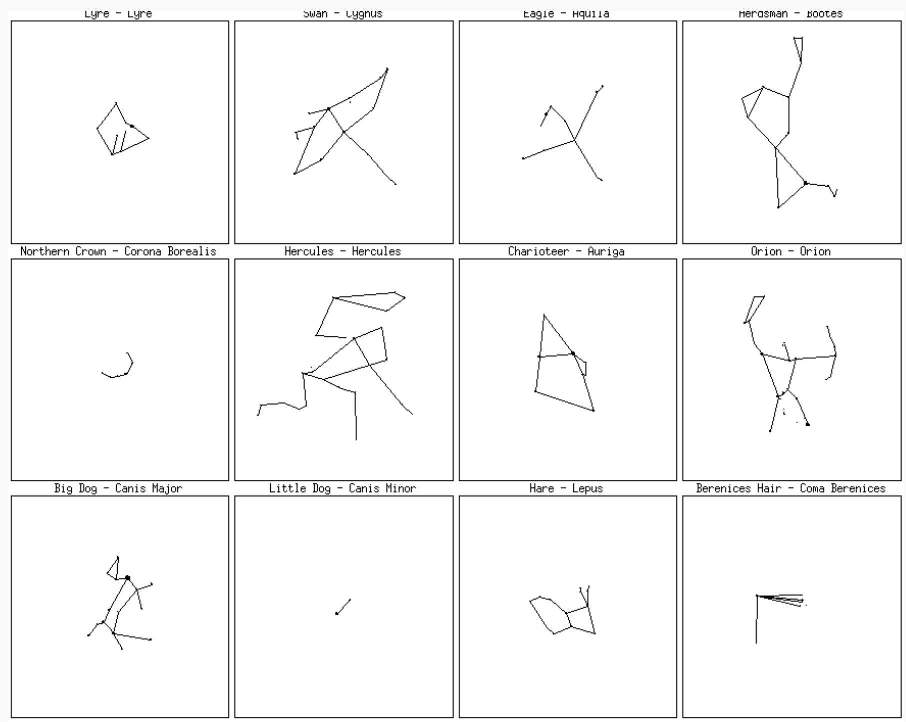
- H. A. Rey ”The Stars, A New Way to See Them”

- H. A. Rey also wrote the “Curious George” books!

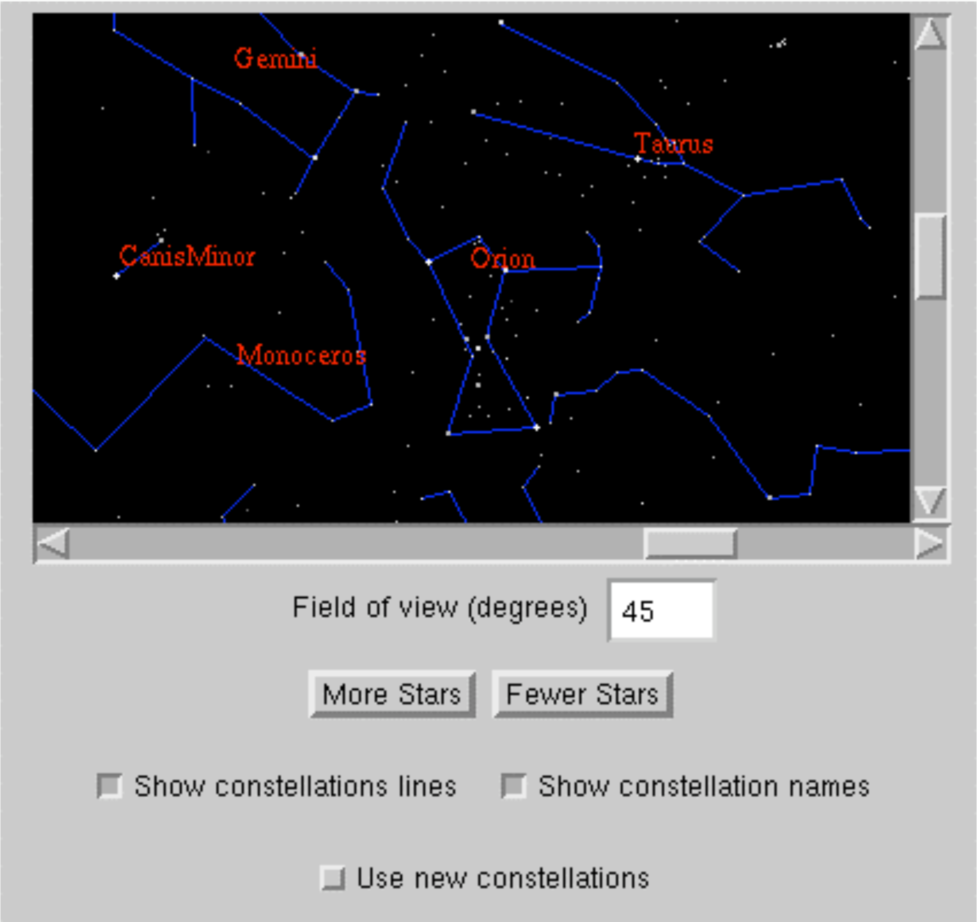


Traditional vs. H. A. Rey





Map of the constellations

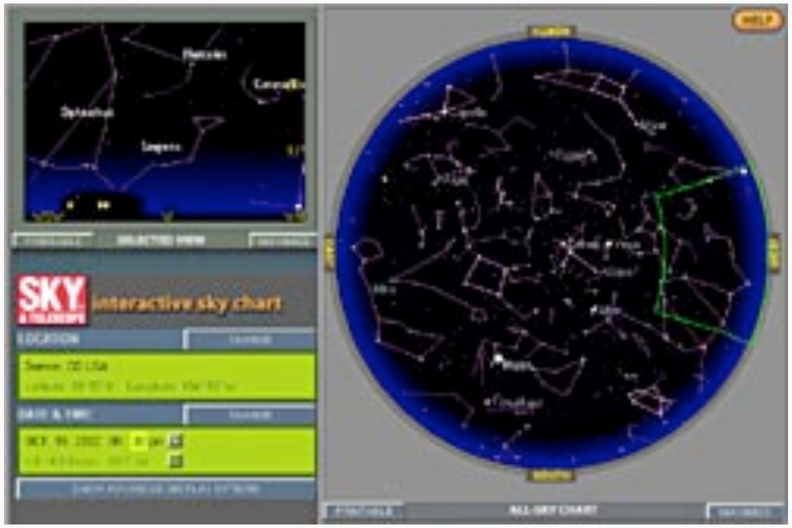


http://www.astro.wisc.edu/~dolan/constellations/constellationjavalist.html

Constellations

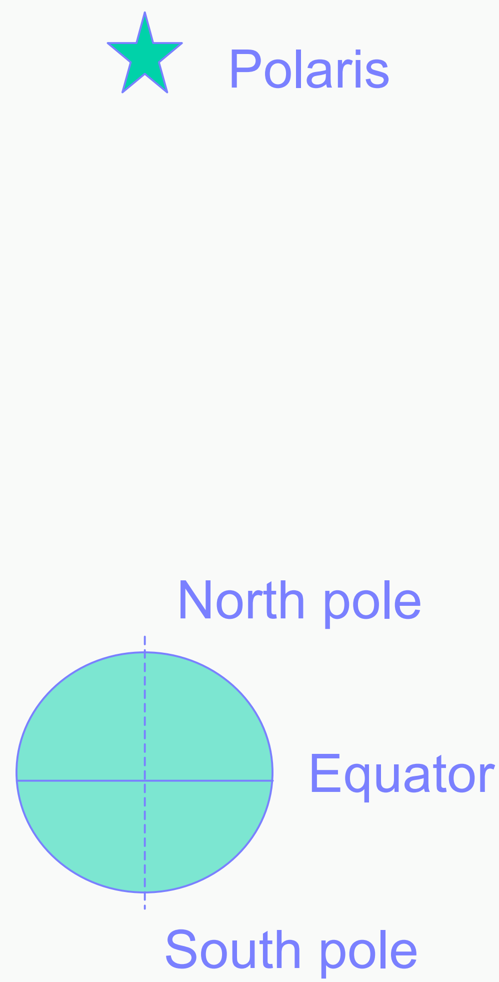
- Planetarium programs often give the option to display constellations using Rey’s or astronomical stick figures.

- The free program on Sky and Telescope’s website uses Rey’s figures! http://skyandtelescope.com/



Polaris - The North Star

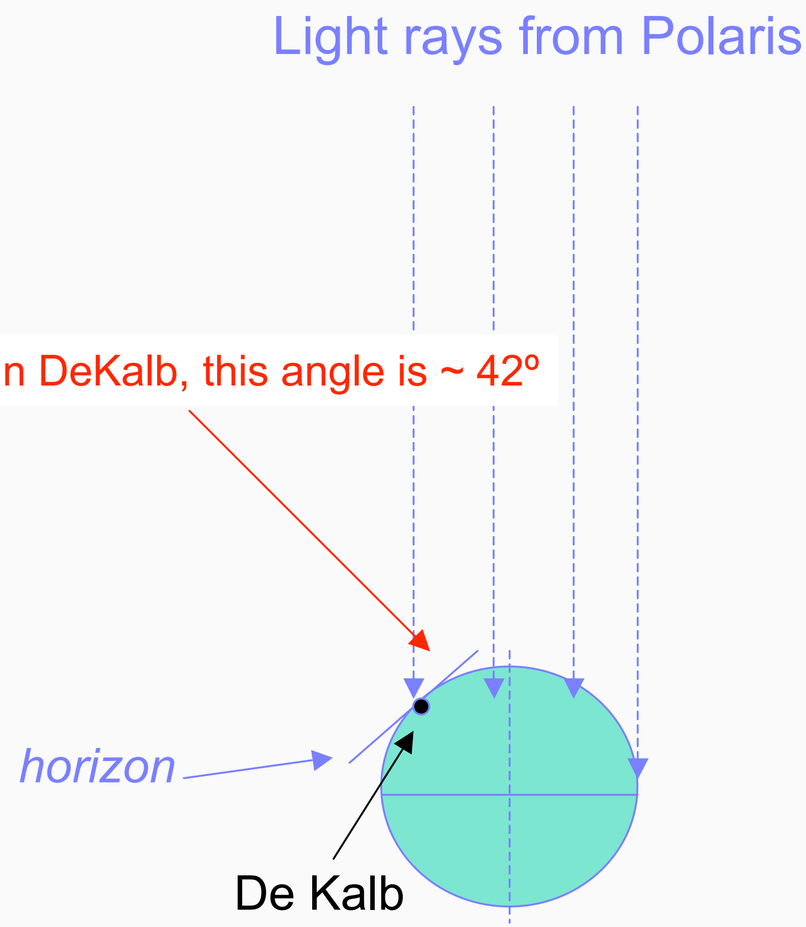
- Polaris is almost directly overhead at the North Pole.
- Polaris is at the north horizon at the Equator.
- Polaris is not visible south of the Equator.
- Other stars appear to move due to the Earth's rotation.



Polaris - The North Star

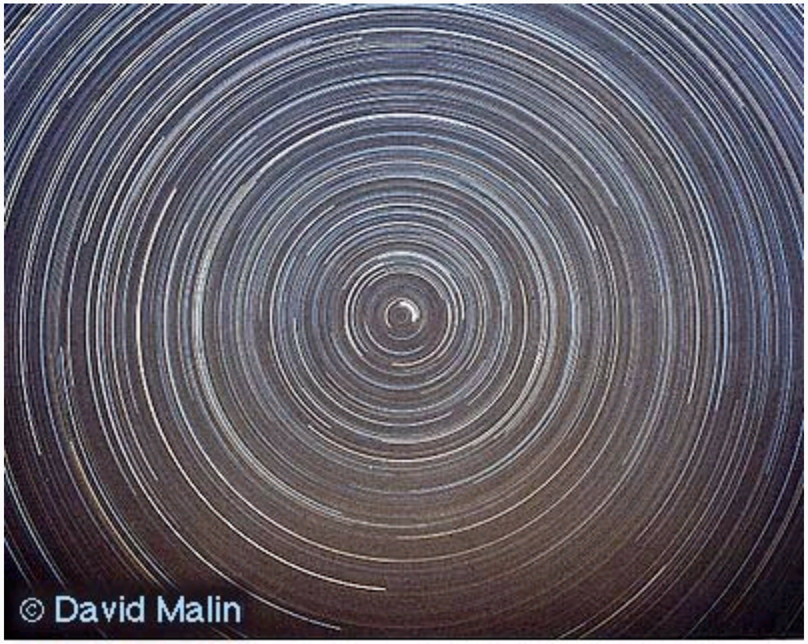
- Polaris is always located above the northern horizon at an angle equal to your latitude

- De Kalb's latitude is about 42º N



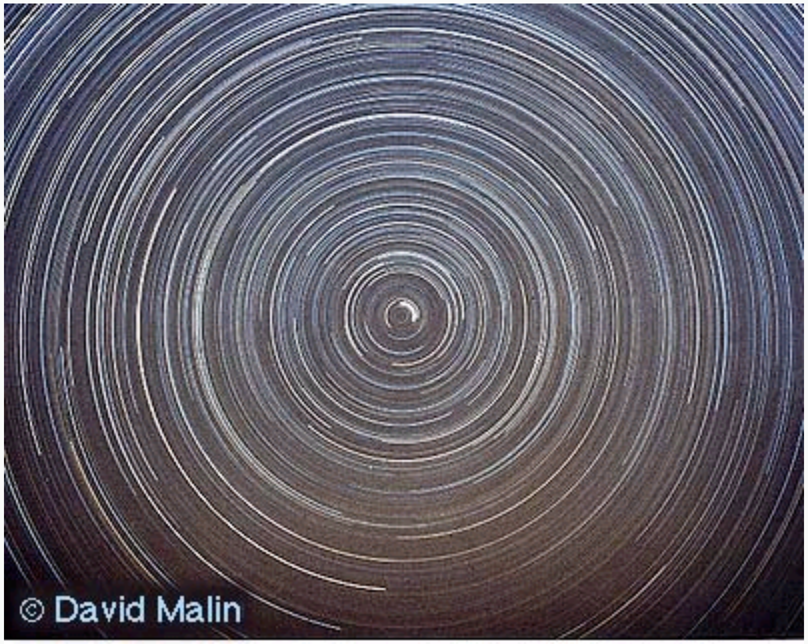
Rising and Setting Stars

- Stars appear to “move” in circles about Polaris.
- This is because the Earth is rotating about the geographic pole.
- It takes 1 day to complete the circle.
- Stars that never rise or set are called *circumpolar* stars



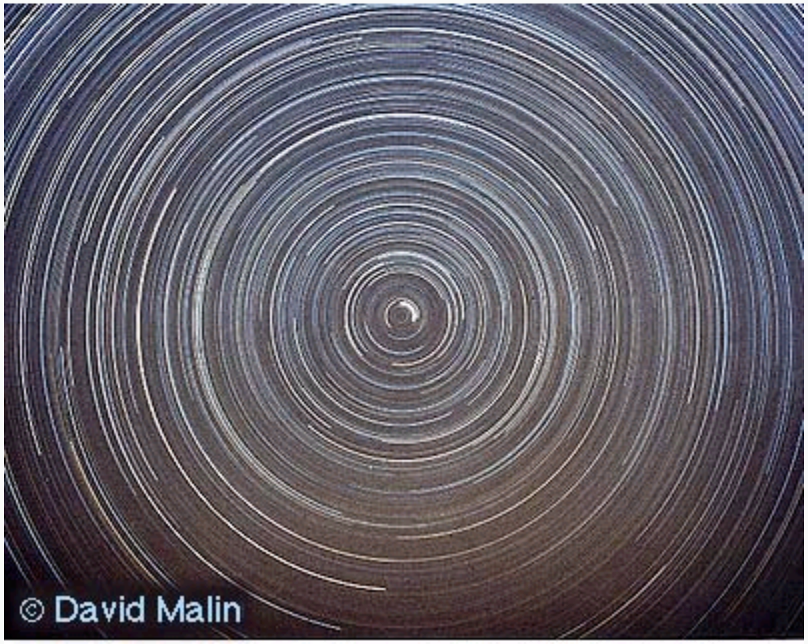
Star trails in the northern sky

- As the earth spins on its axis, the sky seems to rotate around us.
- This motion produces the concentric trails traced by the stars in this time exposure of the night sky.
- The north celestial pole (NCP) is at the center.



Star trails in the northern sky

- The very short bright trail near the NCP was made by Polaris, commonly known as the North Star.
- So this is proof that Polaris is not *exactly* due north.

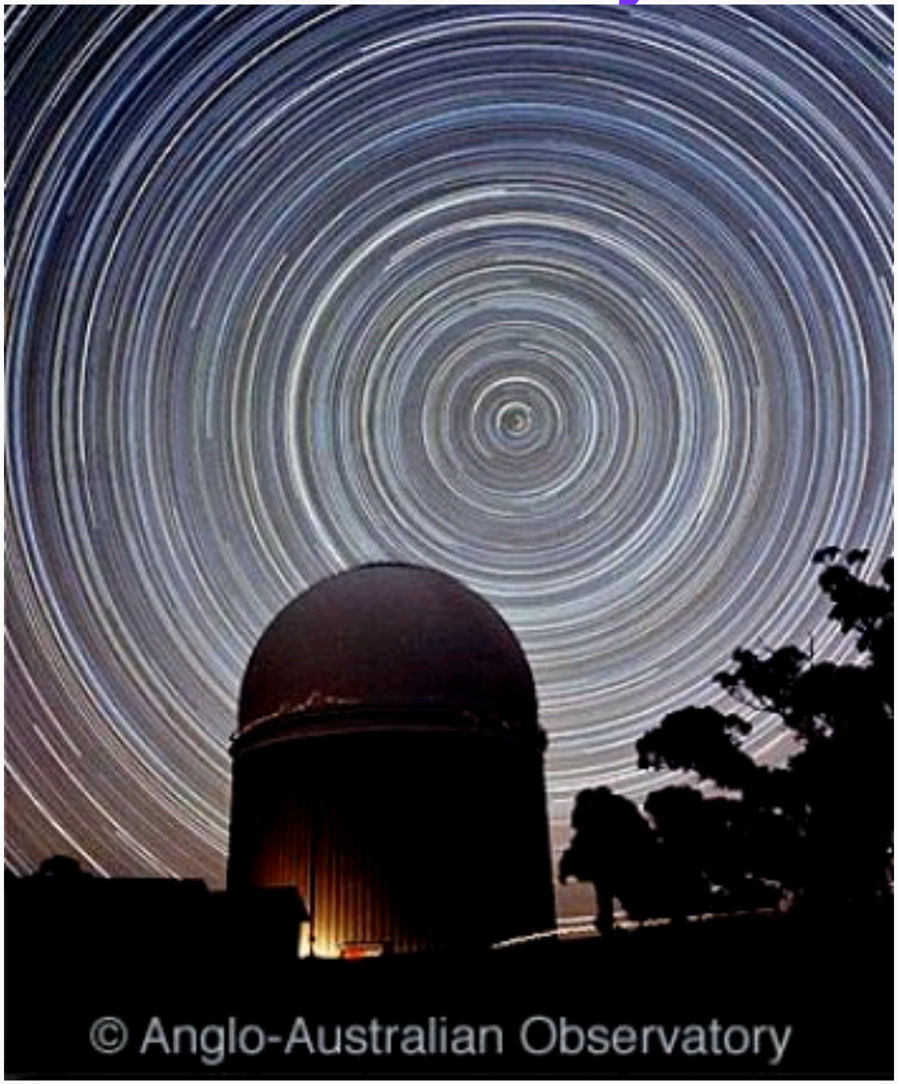


Star trails in the northern sky

- More proof that Polaris is not *exactly* due north.

Star trails in the southern sky

- While the bright star Polaris lies conveniently close to the North Celestial Pole, no bright star similarly marks the pole in the South.
- Still, the South Celestial Pole is easily identified in the picture as the point in the sky at the center of all the star trail arcs.



Calculate time of exposure from star trails

- Measure the angle subtended by the star trails (N deg)
- Then the time of the exposure was:

  (N deg)(1 day/360 deg)(24 hours/day) = X hours


~20degrees

Calculate time of exposure from star trails

- The angle subtended by each star trail is ~20 degrees, so the time of the exposure was:

  (20 deg)(1 day/360 deg)(24 hours/day) = 1.3 hours

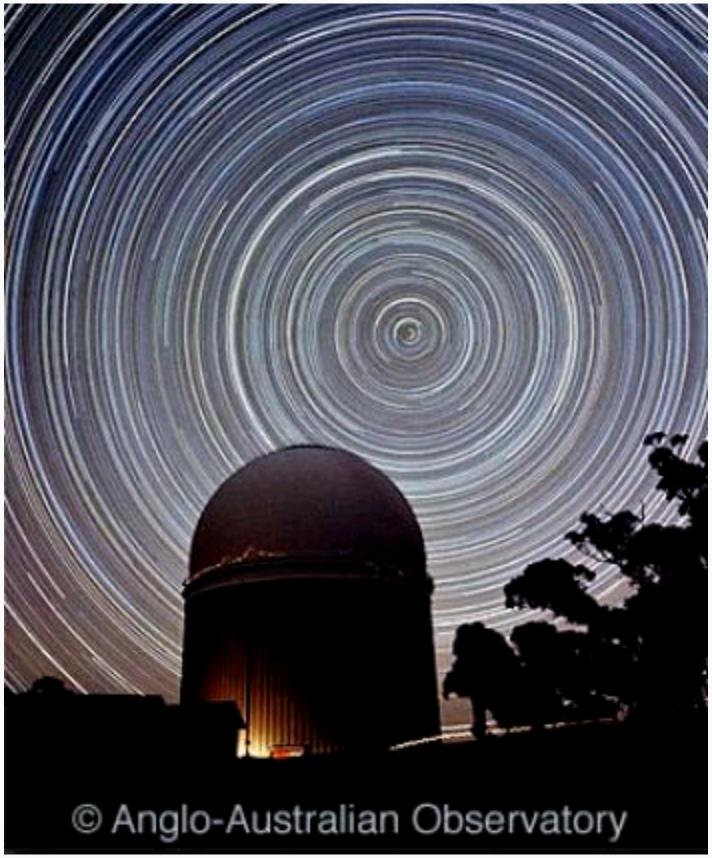
Star trails at mid-latitudes

- Star trails from a lower latitude
- Notice that the trails set beneath the horizon
- These trails were made by stars that are NOT circumpolar stars

Star trails at mid-latitudes

- Star trails from a lower latitude (trails set beneath the horizon)

Compare rising and setting at high and low latitudes



Equatorial mount on Celestron14 as in Davis Hall Observatory, NIU

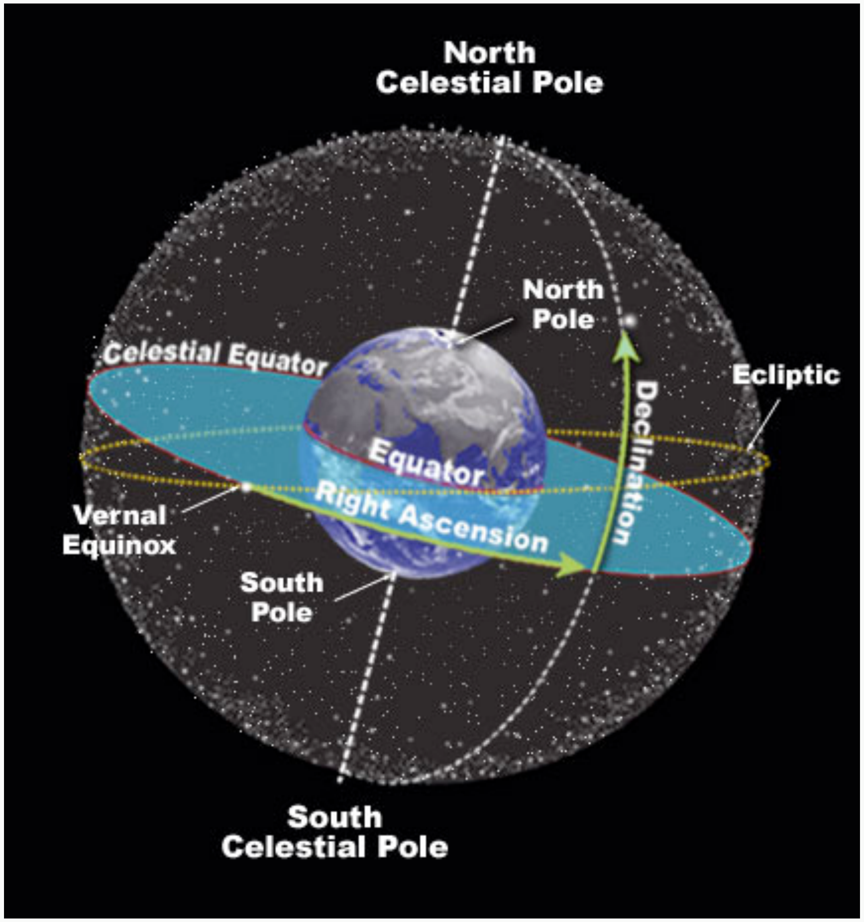
To Polaris

To Polaris

~42 degrees

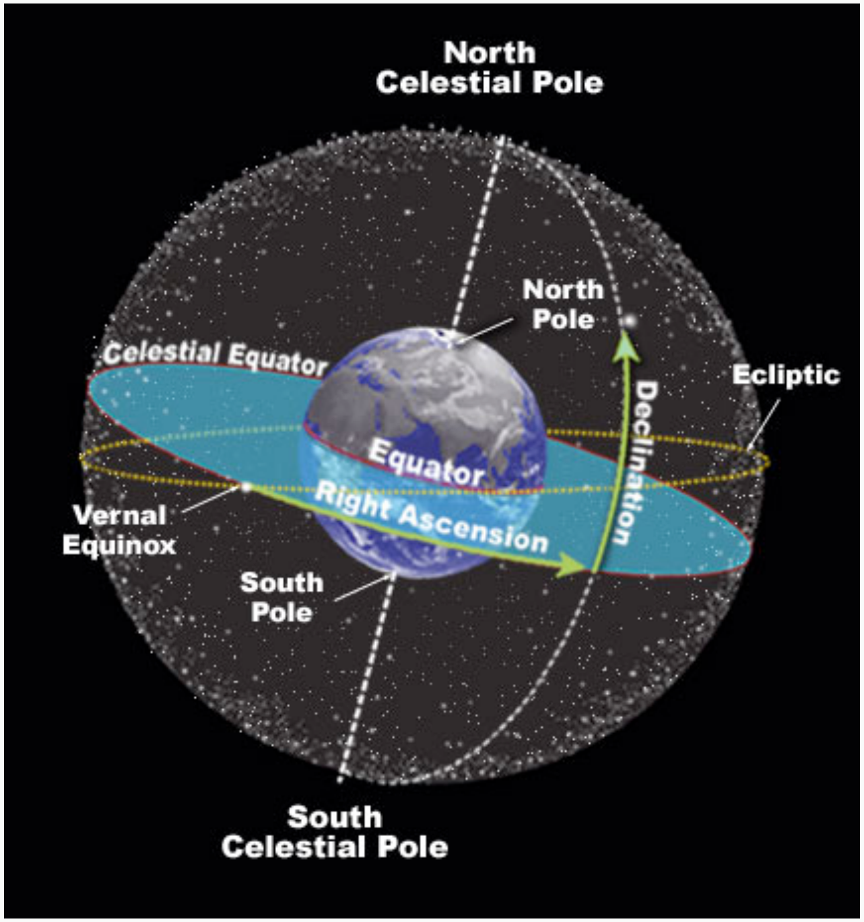
Celestial Sphere

- The stars can be mapped onto a sphere.
- This sphere is called the *celestial sphere*
- Positions correspond to points over locations on earth.



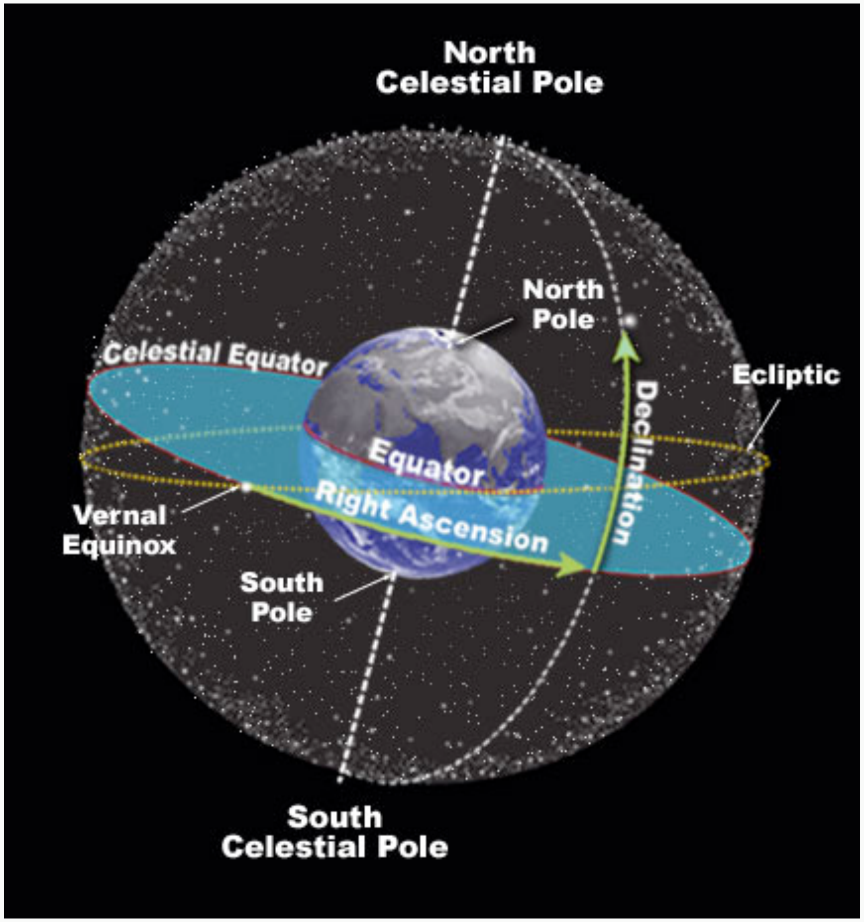
Celestial Sphere

- The North and South Celestial Poles correspond to the Geographic North and South Poles of Earth
- The Celestial Equator corresponds to the Earth's Equator



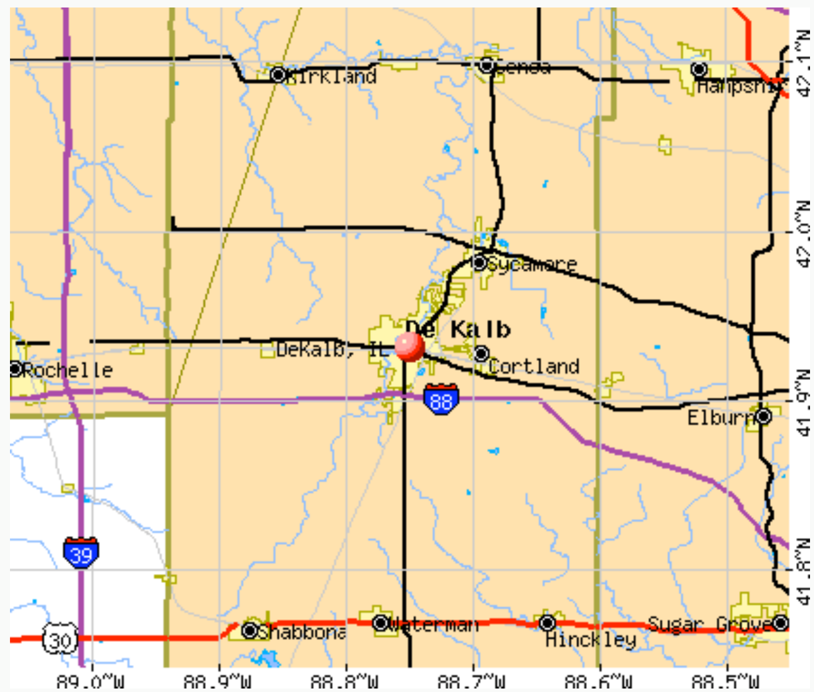
Celestial Sphere

- The coordinates of objects on the celestial sphere are analogous to longitude and latitude



Longitude and latitude

- DeKalb, IL
- Latitude: 41.93 N
- Longitude: 88.75 W



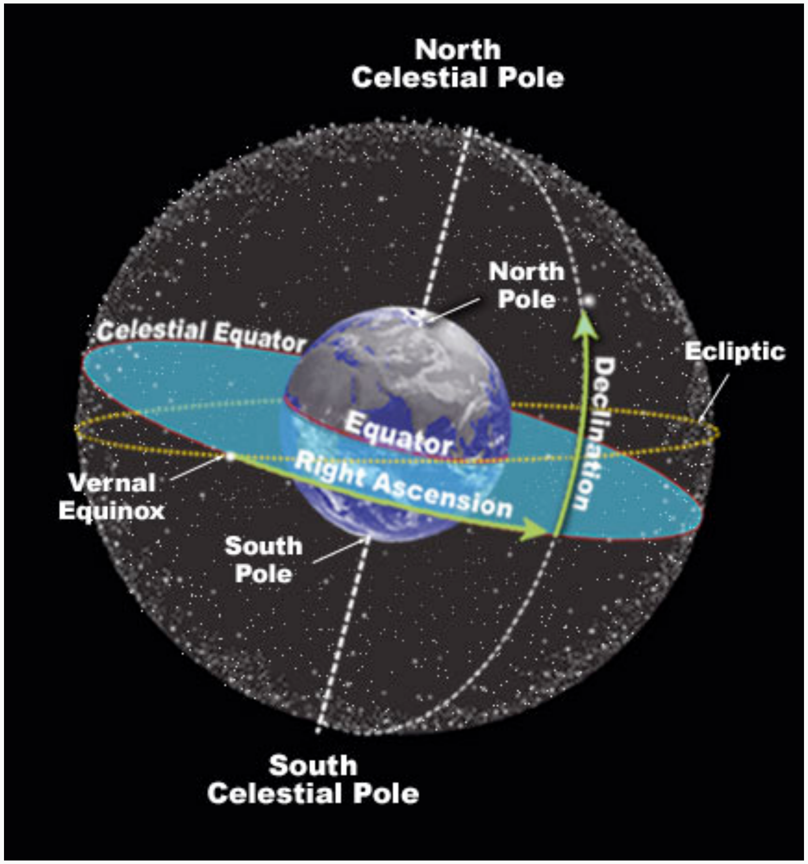
Latitude and declination

Latitude

- Latitude measures the number of degrees north or south of the Equator. DeKalb is at 41.93º N latitude.

Declination

- Stars have a north-south position called the *declination* which is similar to the idea of latitude



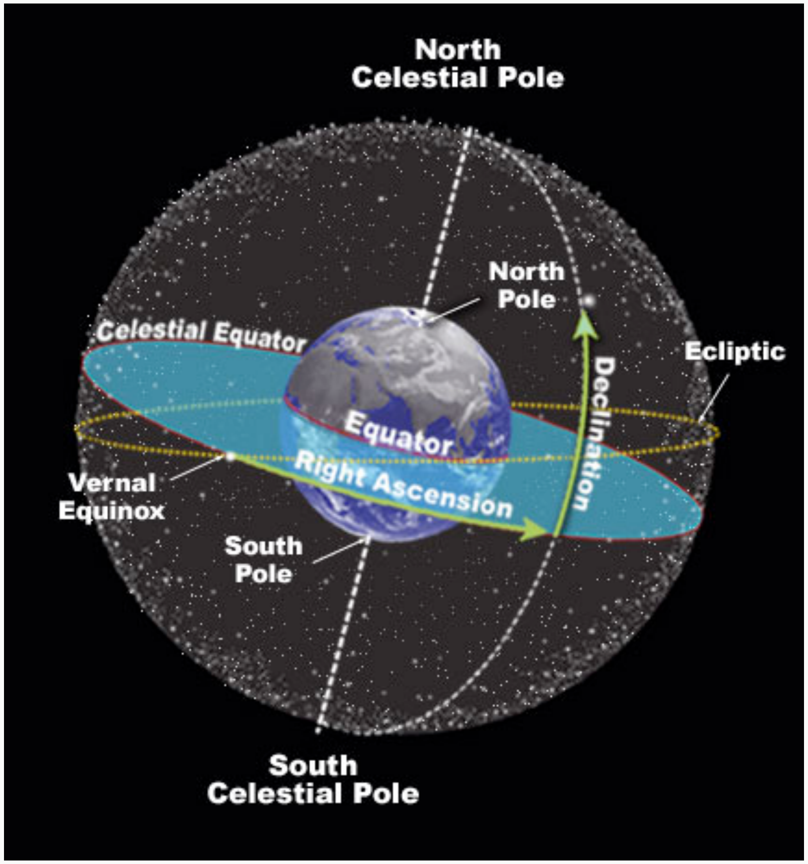
Latitude and declination

Declination

- The declination of a star is the number degrees north or south of the Celestial Equator

- Polaris has a declination of 90º N.

- Stars over the equator have a declination of 0º.



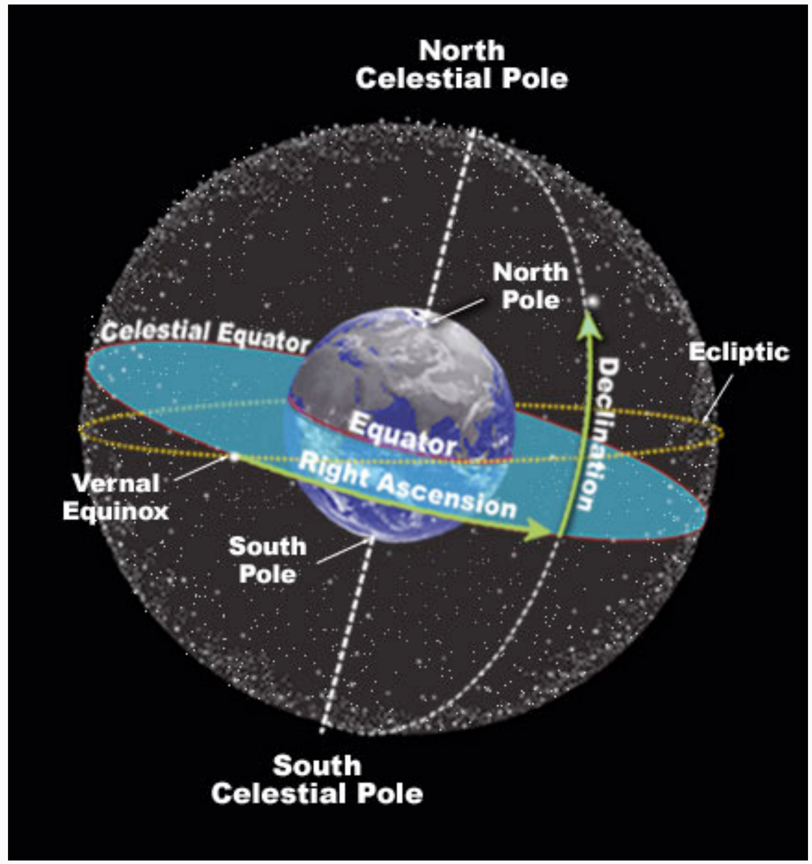
Longitude and Right Ascension

Longitude

- Longitude measures the number of degrees east or west of the Meridian. DeKalb is at 88.75º W longitude.

Right Ascension

- Stars have an east-west position called the *right ascension* which is similar to the idea of longitude.

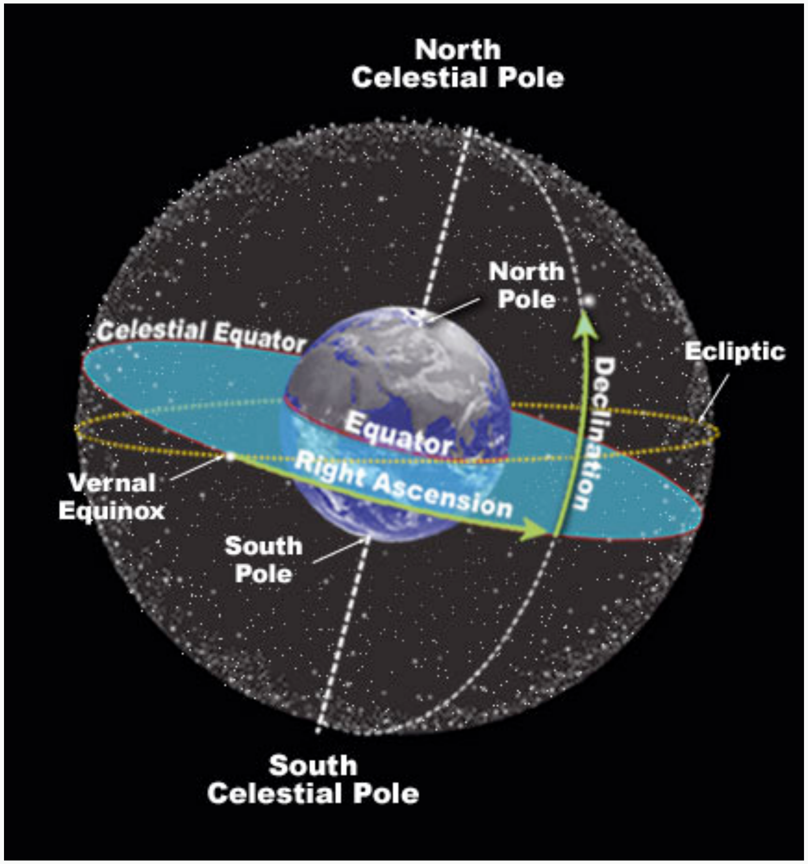


Longitude and Right Ascension

Right Ascension

- The Vernal (spring) equinox is used to define zero hours right ascension.

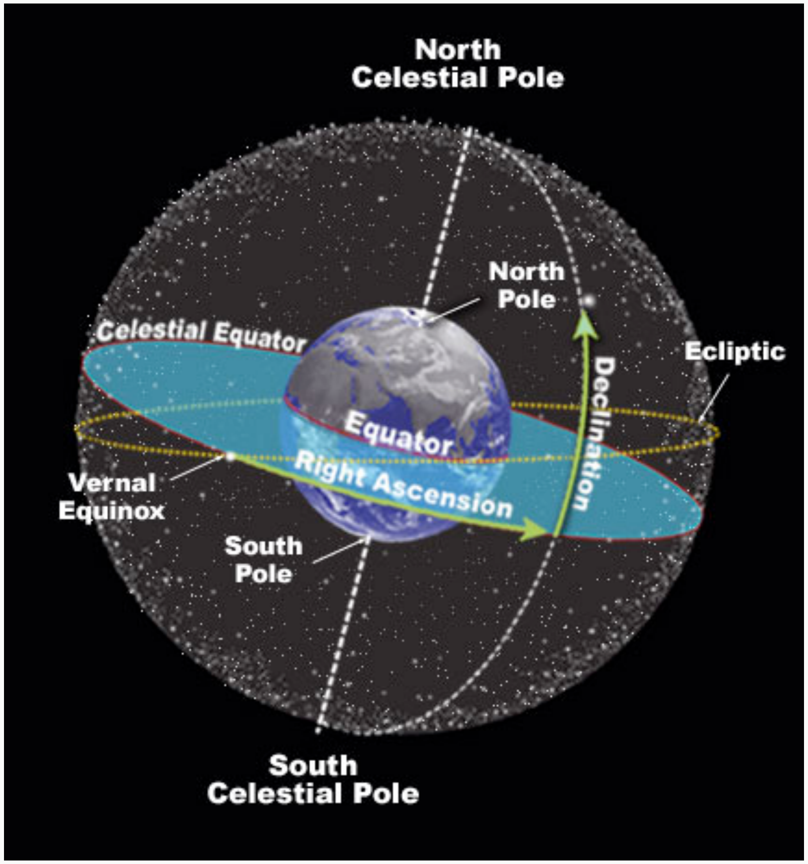
- Right ascension is the number of hours, minutes, seconds east or west of the Vernal equinox



Longitude and Right Ascension

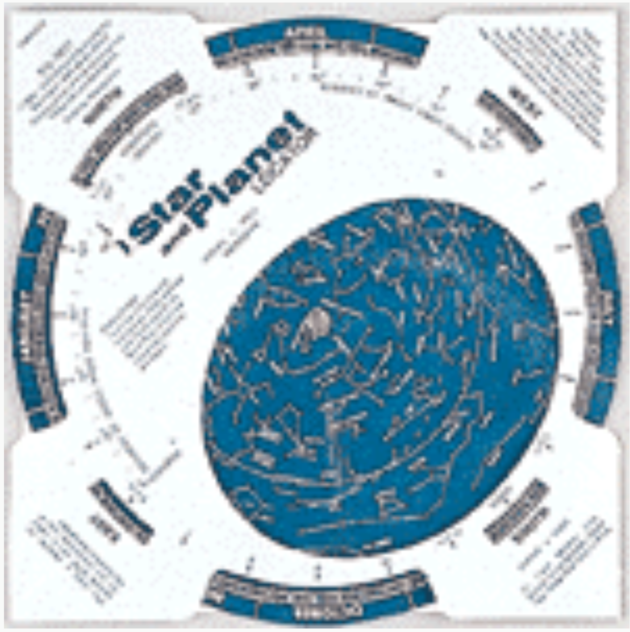
Right Ascension

- Vernal equinox is the point of intersection of the celestial equator and the ecliptic, where the sun crosses the celestial equator moving northward.



Star and Planet locator

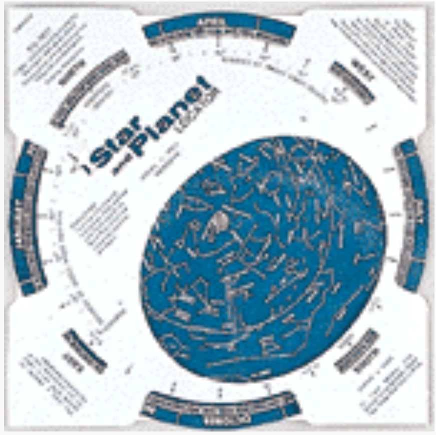
- A Star and Planet Locator is a map of the celestial sphere
- Other names for a Star and Planet Locator are
  - Planisphere
  - Star Finder

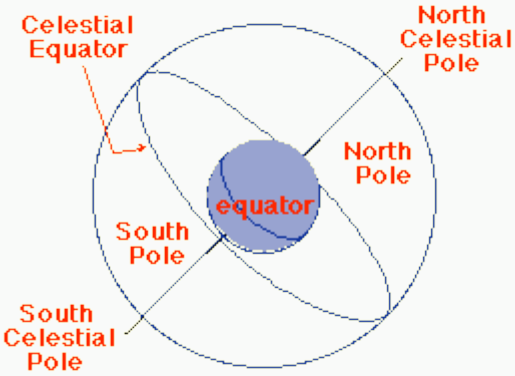


Star and Planet Locator

- The earth turns under the stars, so the stars turn on the Star and Planet Locator.

- Positions correspond to points over locations on earth (to positions on the celestial sphere)

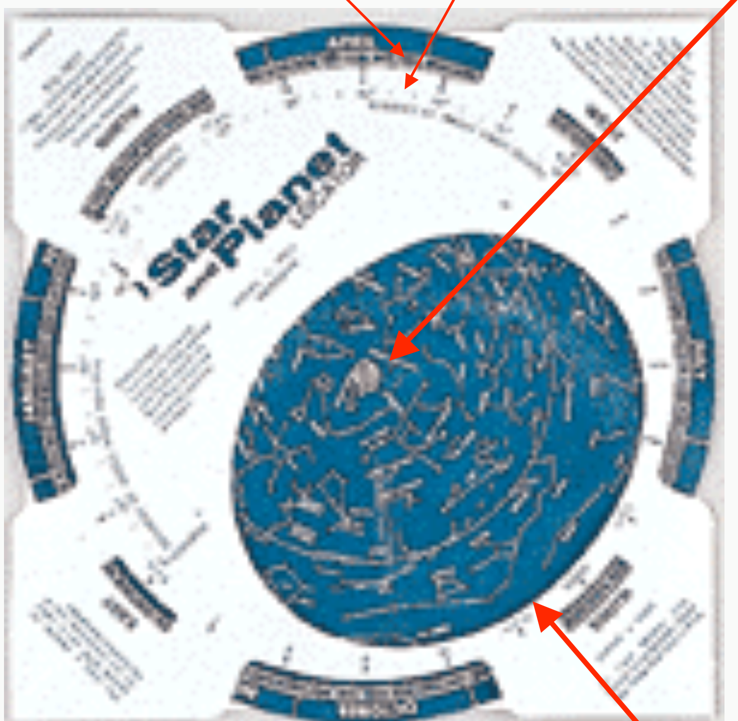


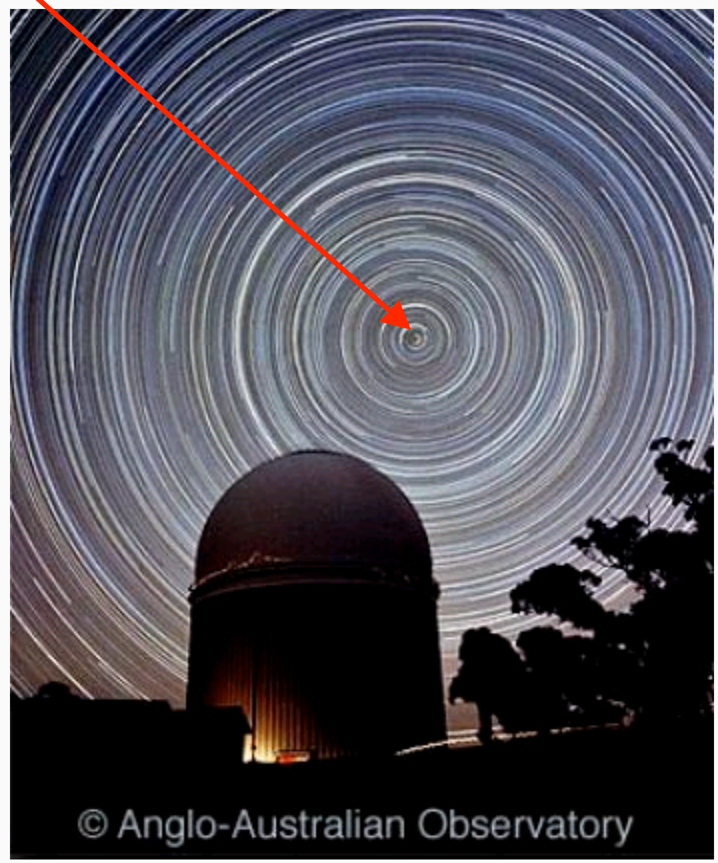


Star and Planet Locator

Date Time

Celestial Pole

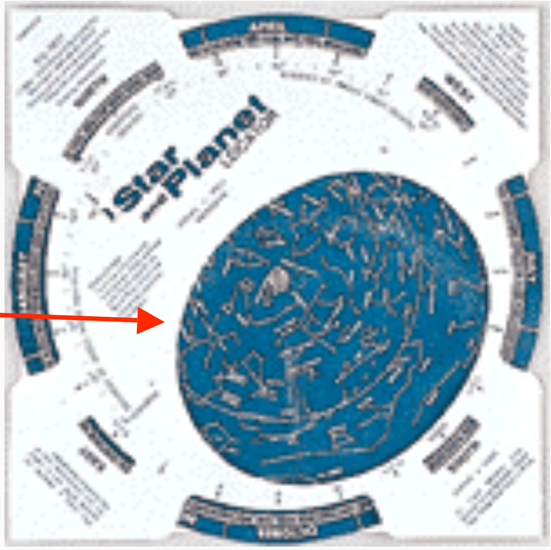




Horizon

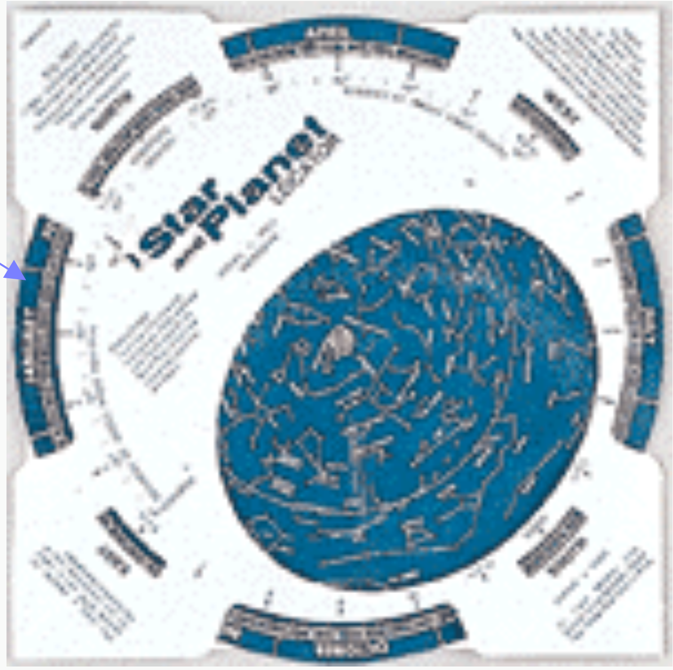
Horizon

- The earth blocks stars too far to the south.
- The *horizon* is the line of the ground for an observer.
- A star finder provides a cover that act as the horizon.
  - *You use a different cover depending on your latitude*



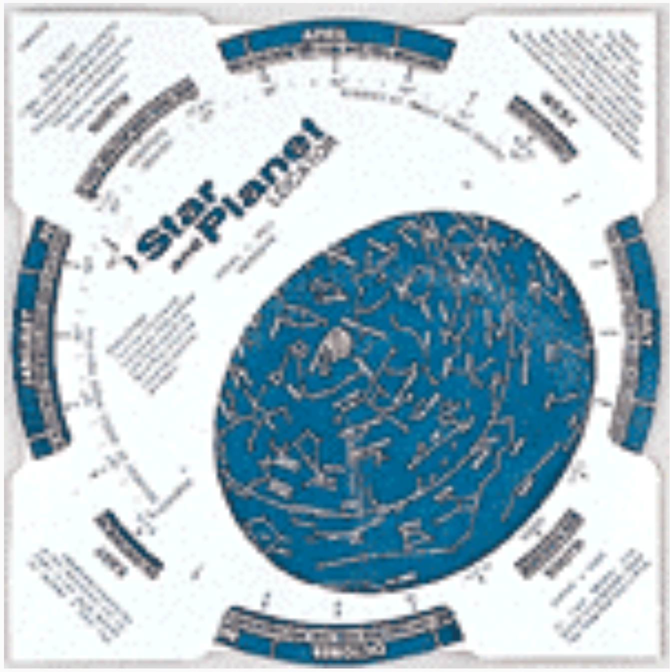
Line up the time to the date

- The wheel turns to set the day and time for the observer.



Using the Star and Planet Locator

- The Star and Planet Finder mimics the Earth's daily rotation and yearly revolution about the Sun

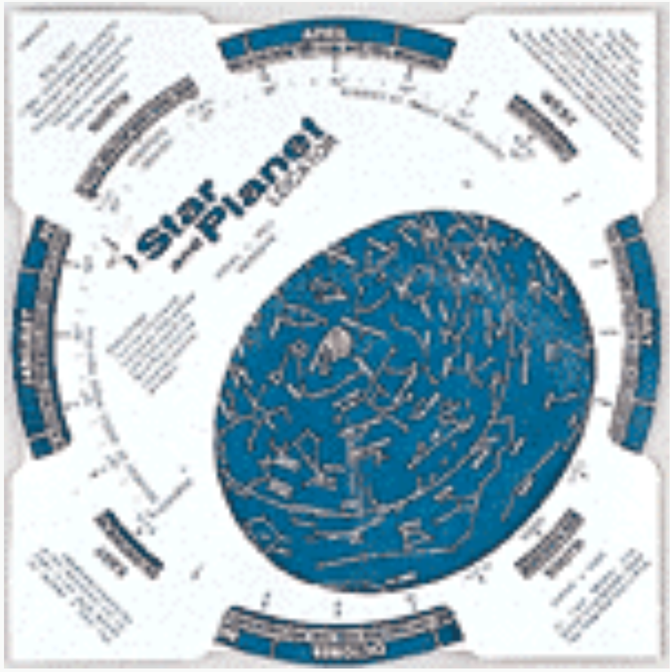


Using the Star and Planet Locator

- Stars "move" east to west over the course of one night in circle about the North Celestial Pole

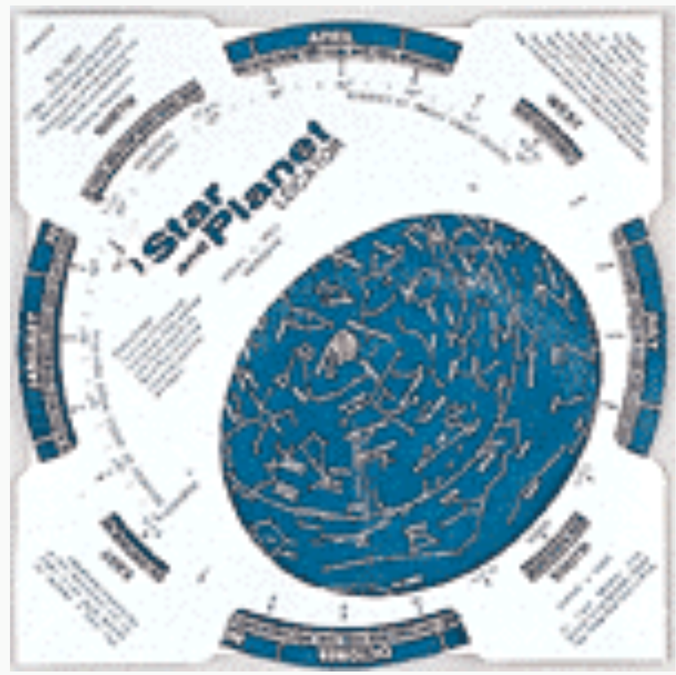
- As you spin the disk CCW, see how new stars 'appear' from under the eastern horizon and stars 'disappear' under the western horizon

- This illustrates the rising and setting of stars



Using the Star and Planet Locator

- Stars “move” east to west by 2 hours per month and “return” to the same position after one year
- This is due to the difference between the solar and sidereal day (described a few slides later)



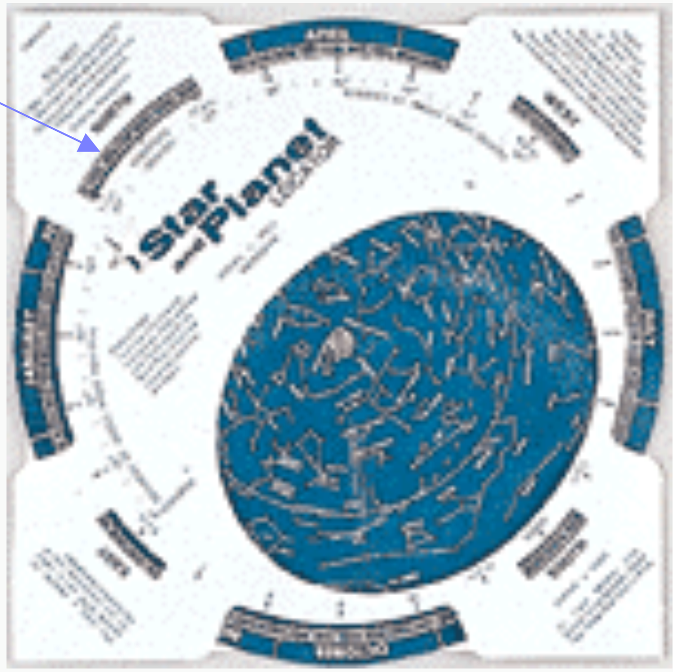
Using the Star and Planet Locator

- Notice that the days are separated by 1 degree.

- So for the same time on successive nights, the stars' positions have shifted

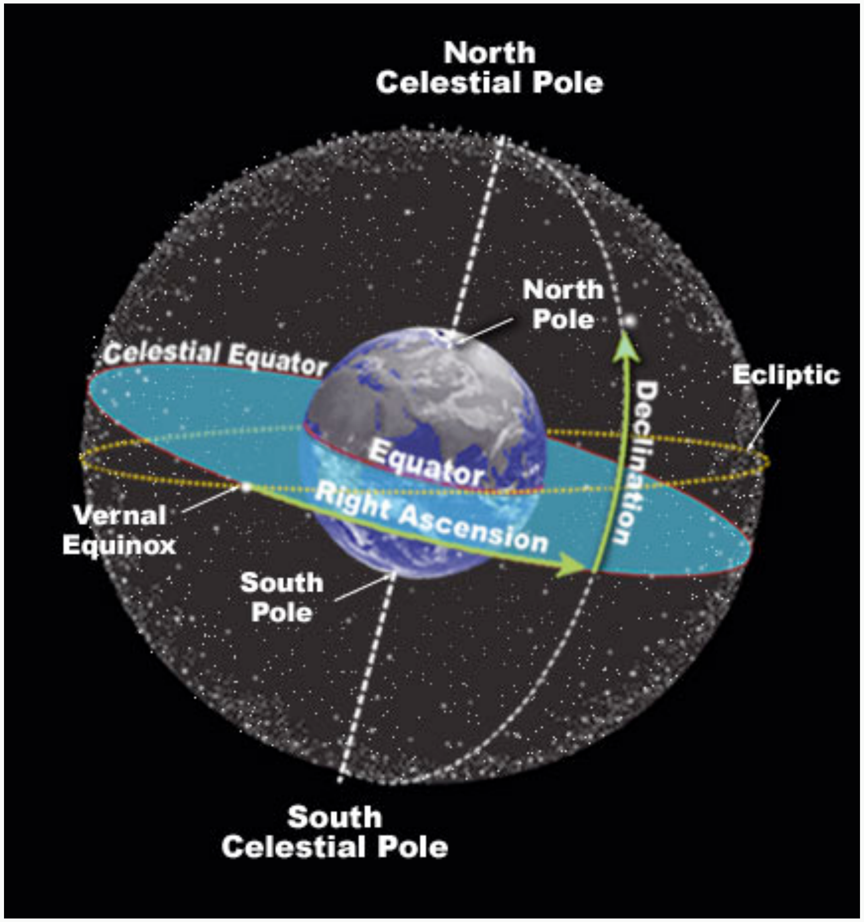
- Stars rise ~4 minutes earlier each day

- (1 day)(24 hours/day)(60 min/hour)=4 min



Ecliptic

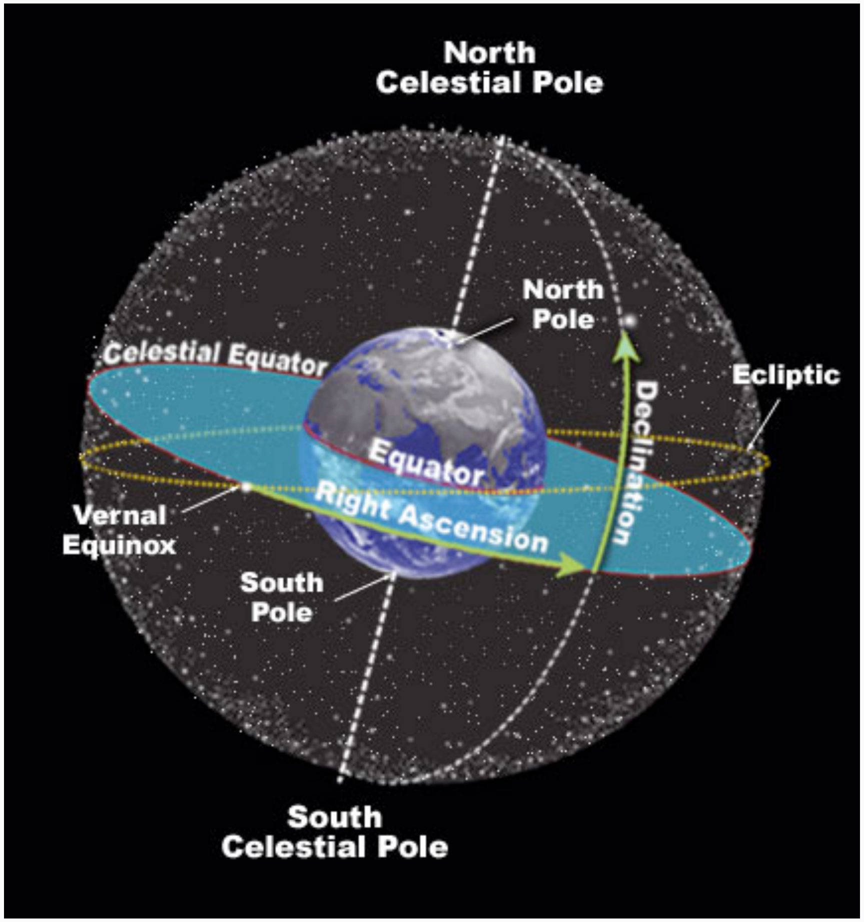
- The ecliptic is the plane described by the Earth's path around the Sun



Ecliptic

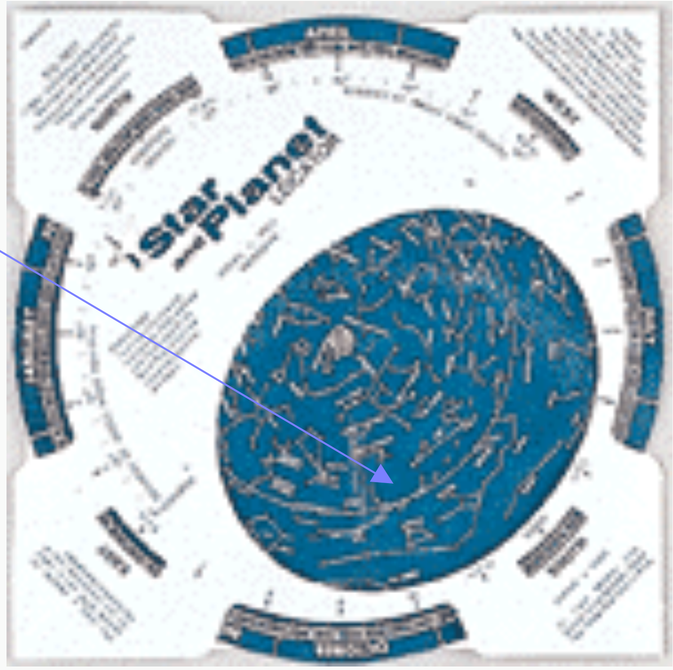
- The ecliptic and celestial equator are different circles tilted 23.5 degrees with respect to each other on the celestial sphere

- This is because the earth's axis of rotation is tilted 23.5 degrees from the plane of the ecliptic



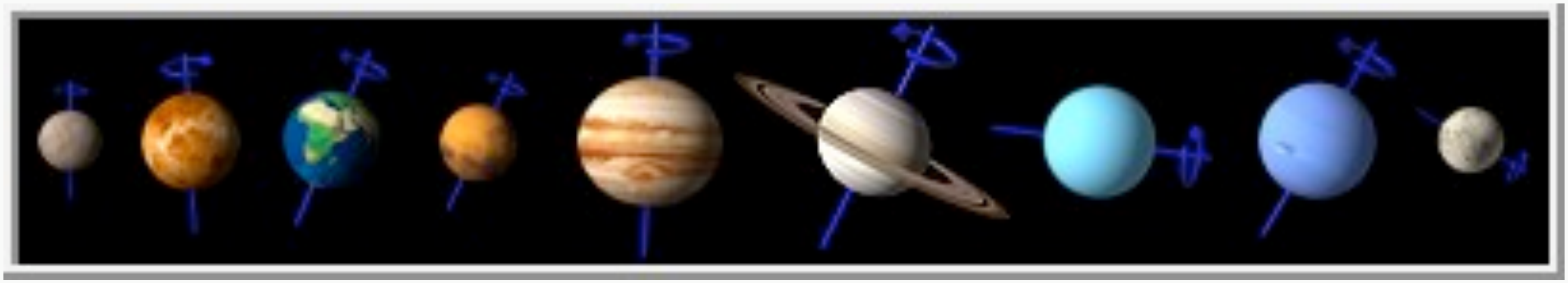
Ecliptic

- The ecliptic is indicated by dashes on a Planisphere



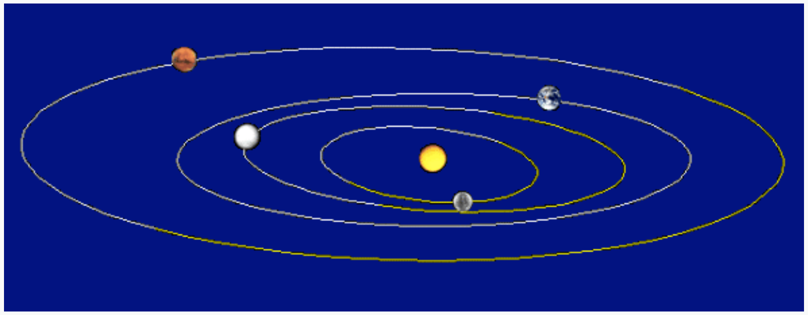
Ecliptic

- Each planet, including the Earth's, axis of rotation is inclined to the plane of the ecliptic.

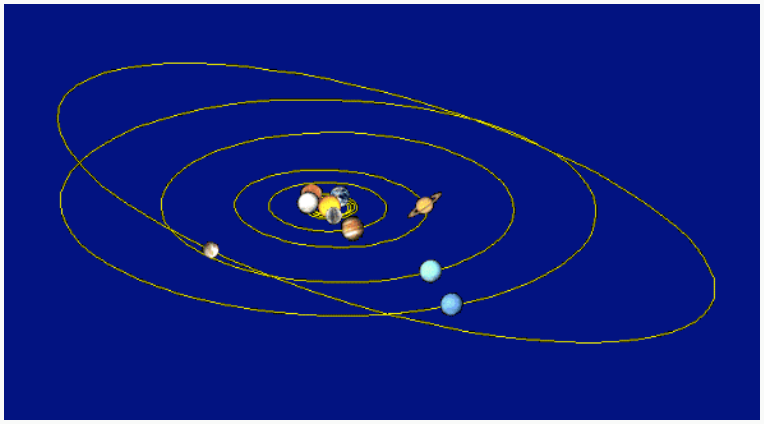


Ecliptic

- The orbit of the Moon and the orbits of many of the planets lie near the plane of the ecliptic



Inner planets



Inner and outer planets

Ecliptic

- The Plane of the Ecliptic is illustrated in this Clementine star tracker camera image which reveals (from right to left) the Moon lit by Earthshine, the Sun's corona rising over the Moon's dark limb, and the planets Saturn, Mars, and Mercury.

Stars vs. Planets

- How can you tell the difference between a star and a planet?

Stars vs. Planets

- How can you tell the difference between a star and a planet?
- The differences seen in this image are enumerated on the following slides

Stars vs. Planets

- Image of Jupiter and Saturn
- Among the background stars are the familiar Pleiades (above right) and V-shaped Hyades (below left) star clusters
- Animated sequence combining 23 pictures taken at approximately 2 week intervals from June 2000 through May 2001.

Stars vs. Planets

Stars

- Stars are very numerous.

Planets

- Planets are few in number (5 are visible to the unaided eye).

Stars vs. Planets

Stars

- Stars are “fixed” relative to each other.

Planets

- Planets “wander” relative to the fixed stars. So they are not in the same location each night nor in the same position year to year

Stars vs. Planets

Stars

- Stars have a wide range of declination and right ascension

Planets

- Must be on (or very near) the ecliptic

Stars vs. Planets

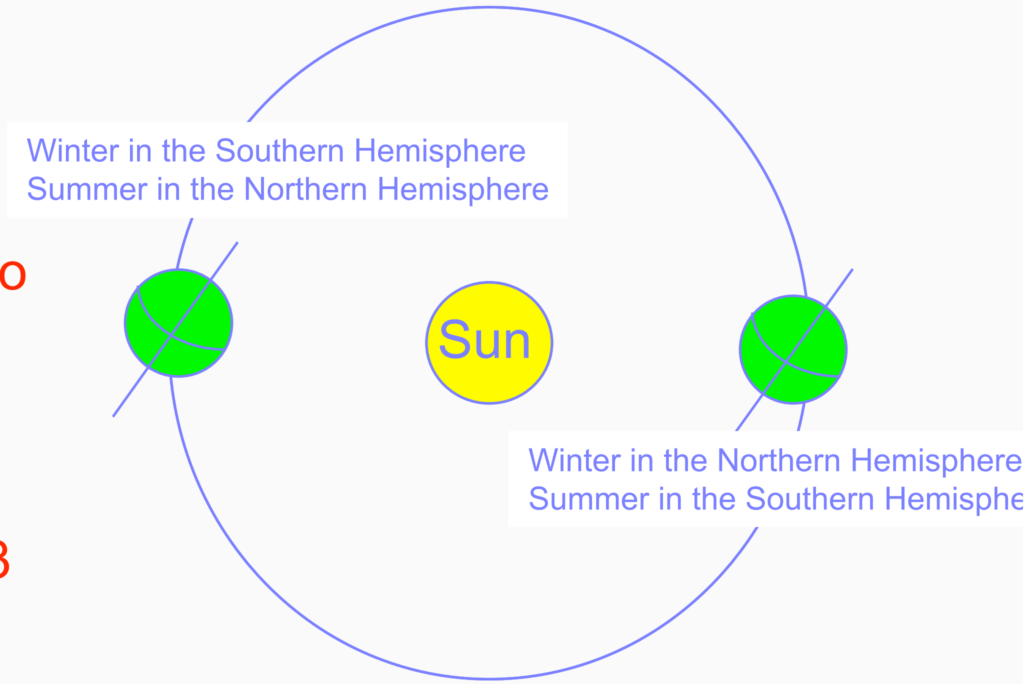
Stars	*Planets*
• They produce their own light independent of the Sun's location.	• Their brightness <u>does</u> depend on the Sun's location.
• Stars twinkle	• Planets don't twinkle
• They are very far away	• Relative to the stars, they are near to Earth.

Chapter 1
Discovering the Night Sky

- Scales of the Universe
- Patterns of Stars
- *Earthly cycles*
- Eclipses

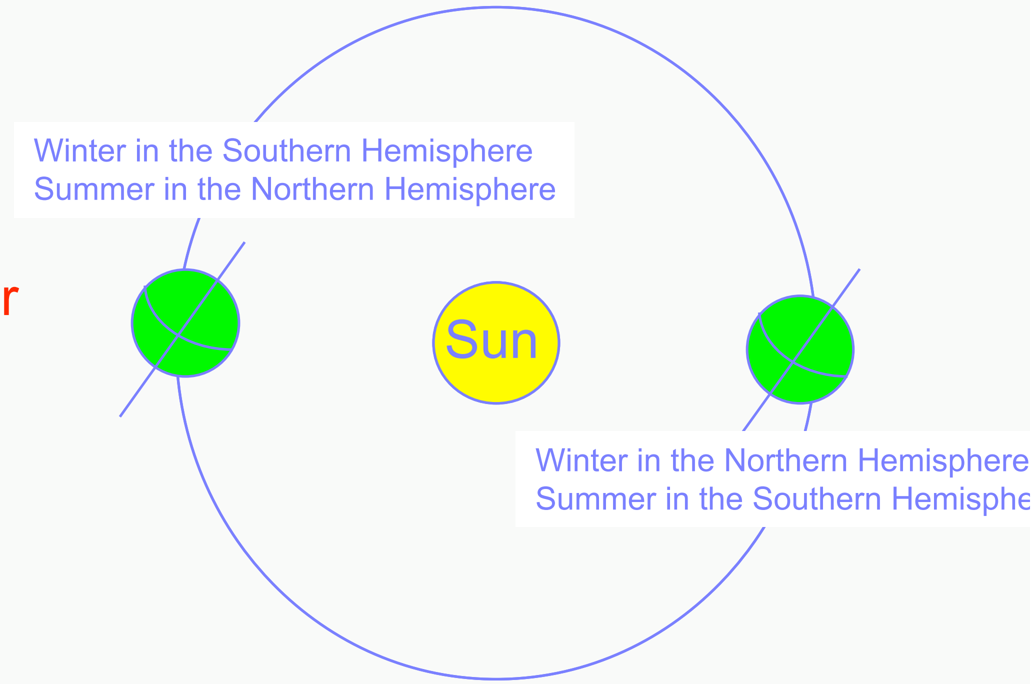
Seasons

- The seasons are caused by the tilt of the Earth's axis of rotation
- The seasons are *NOT* due to the nearness of the Earth to the Sun
- In fact, the Earth is closest to the Sun around January 3 of each year!



Seasons

- In summer, the Sun is more directly overhead in the northern hemisphere.
- The Sun is also hitting us for more hours each day.
- Hence it's warmer in the summer.
- *Seasons Movie*



http://sealevel.jpl.nasa.gov/overview/climate-spherical.html

Diurnal and Annual Motion

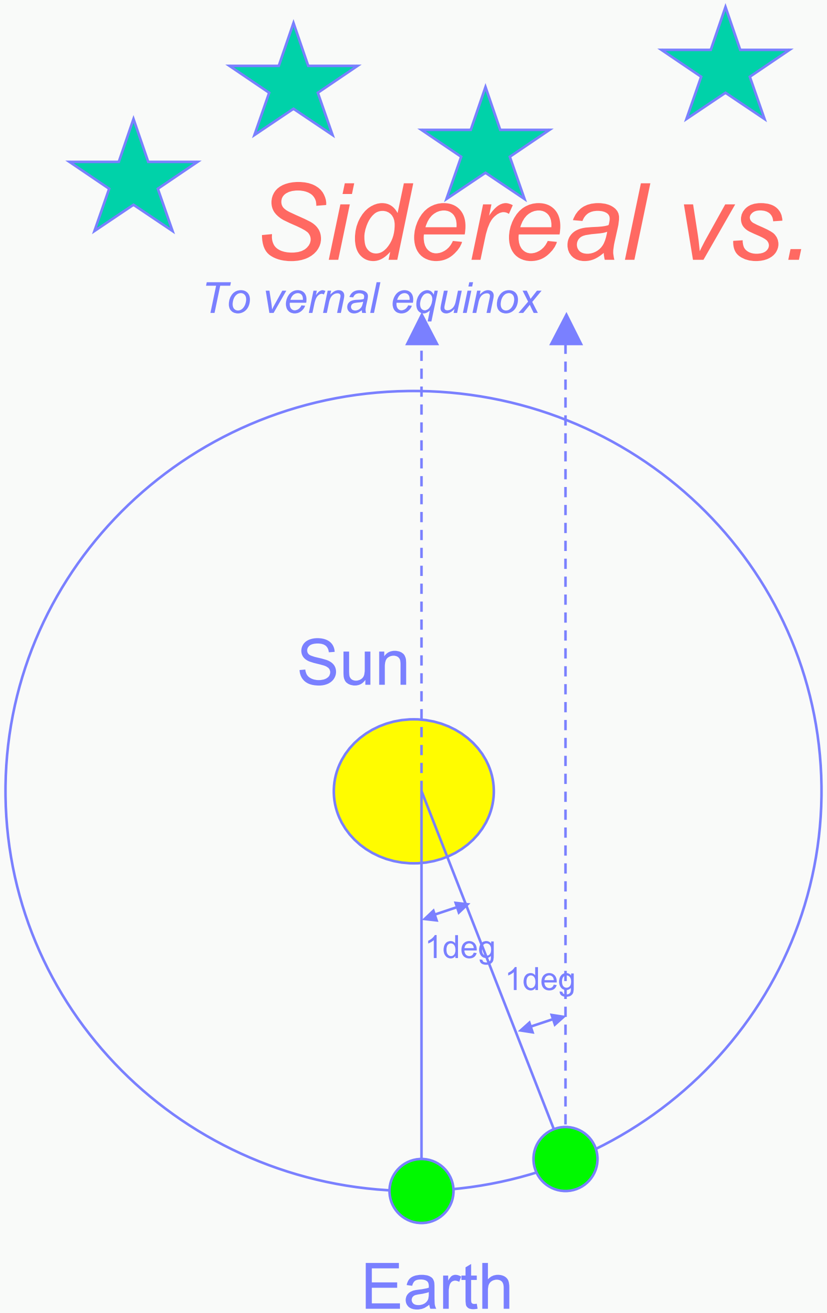
Diurnal (*daily*) motion

- Earth spins once per day.
- Such motion is called *rotation*
- Causes stars to appear to move east to west over the course of one night in a circle about the North Celestial Pole.

Annual (*yearly*) motion

- Earth orbits the Sun once per year
- Such motion is called *revolution*
- Causes each star to rise approximately 4 minutes earlier each night than it did the night before

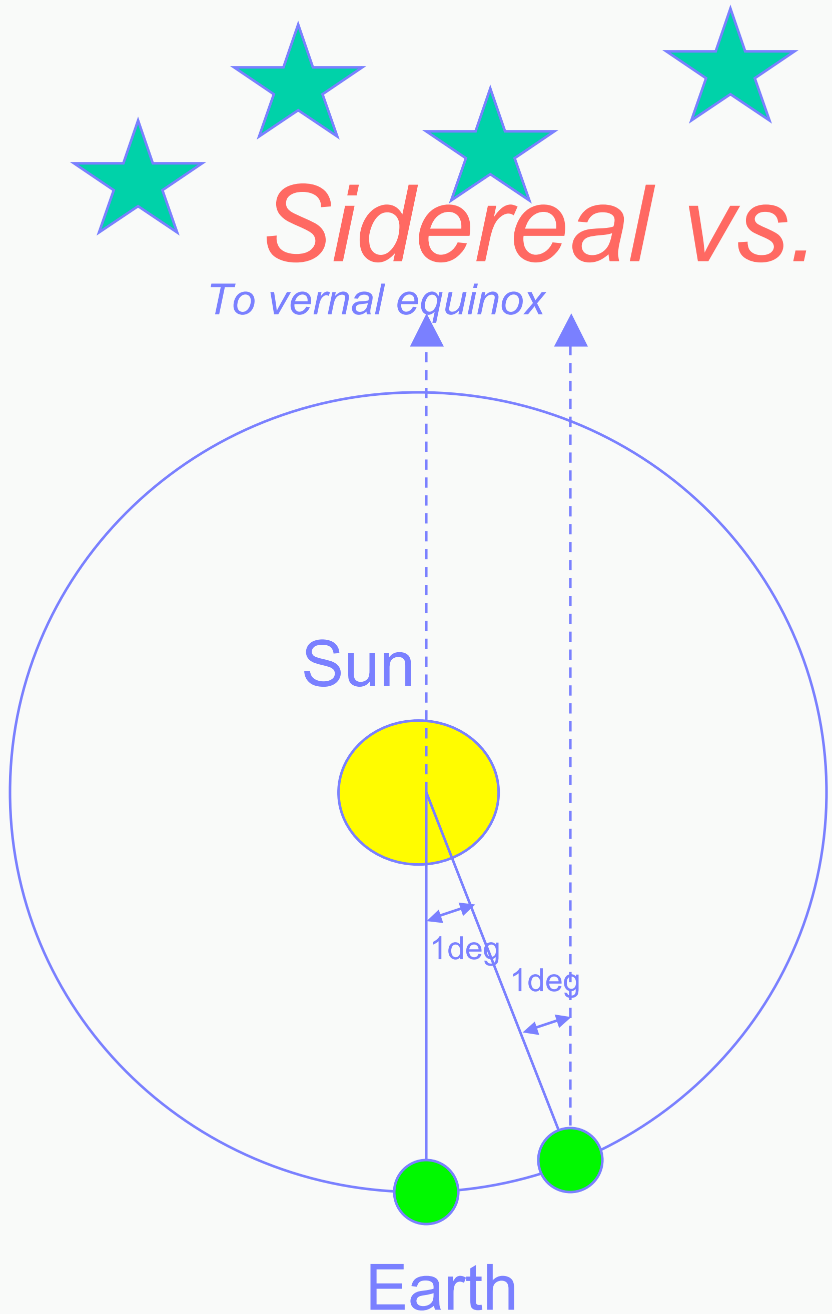
Sidereal vs. Solar day



Sidereal refers to *stars*

Solar refers to the *Sun*

Sidereal vs. Solar day



Because the Earth moves along its orbit around the Sun, the Earth must rotate an extra degree (~361 deg) to get from one local noon to the next.

This extra degree of rotation corresponds to four minutes of time.

Sidereal day = 23h 56m 4.091s

Solar day = 24 hours

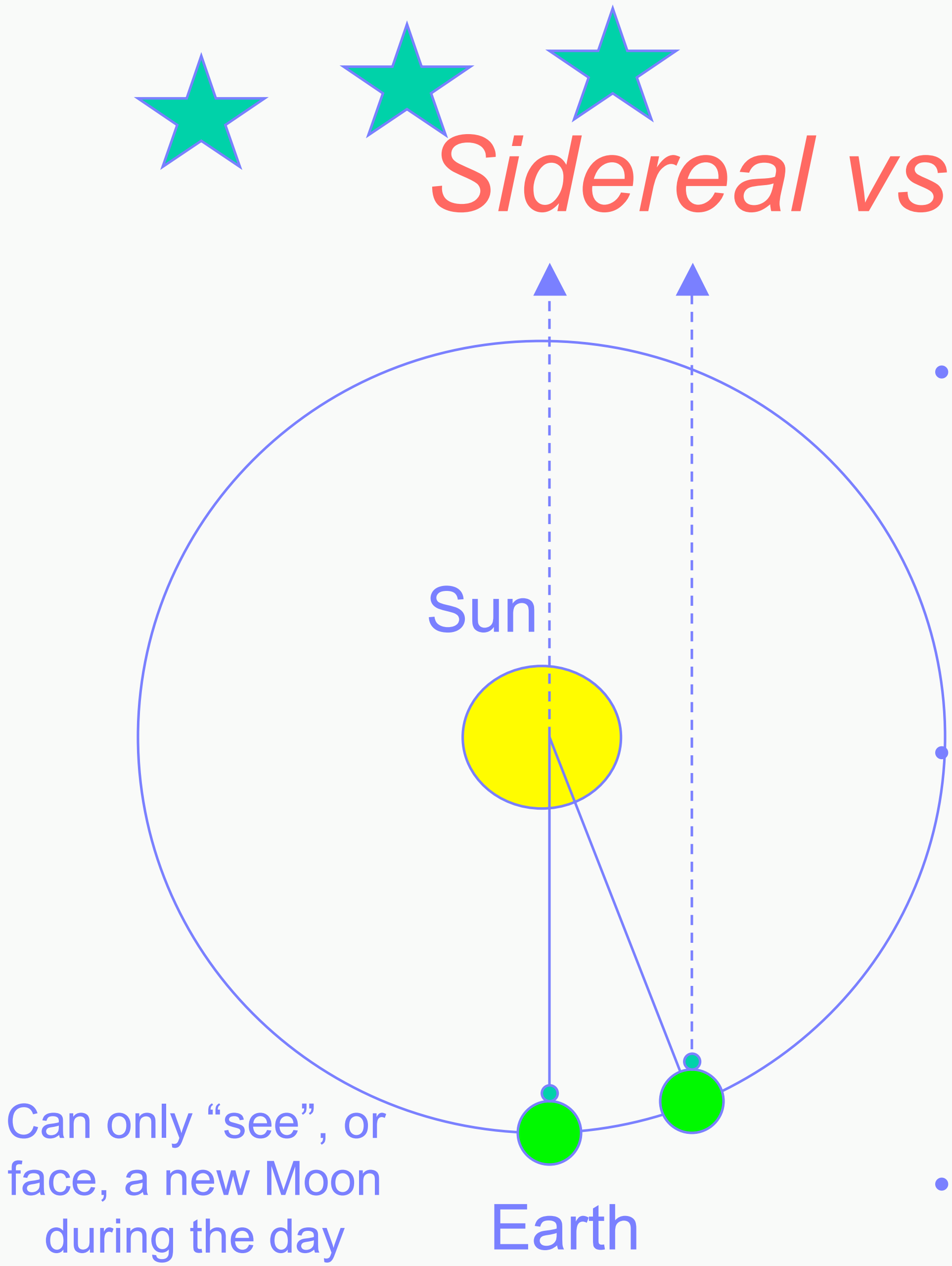
Synodic vs. sidereal month

- A *synodic* month (29.5 days) is the time it takes the Moon to complete a full cycle of phases.

- A *sidereal* month (27.3 days) is the time it takes for the Moon to complete one 360 degree orbit about the earth.

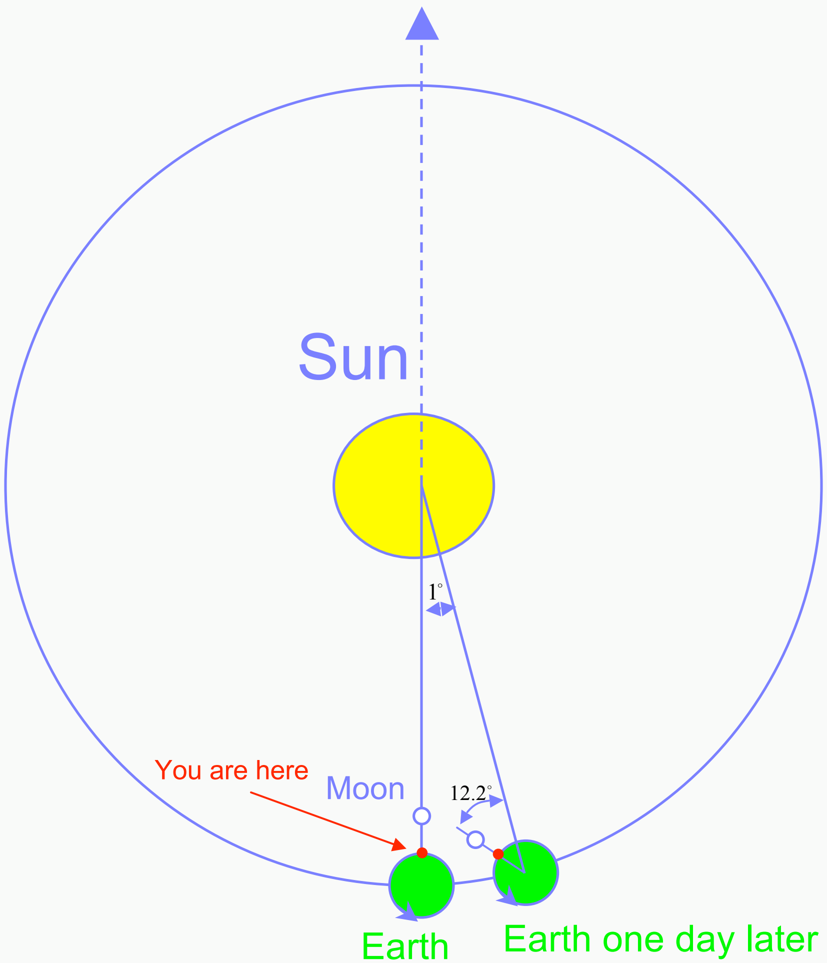
- The difference is due to the earth's constant motion in its orbit about the sun; the Moon must travel through >360 degrees to get from one new Moon to the next.

Sidereal vs. synodic month



- The *sidereal* month is the time the Moon takes to complete one full revolution around the Earth with respect to the background stars.
- However, since the Earth is constantly moving along its orbit around the Sun, the Moon must travel slightly more than 360 degrees to get from one new moon to the next.
- Thus the *synodic* month is longer than the sidereal month.

The moon rises ~50 min later each day



The Moon takes ~ 29.5 days to orbit the earth.

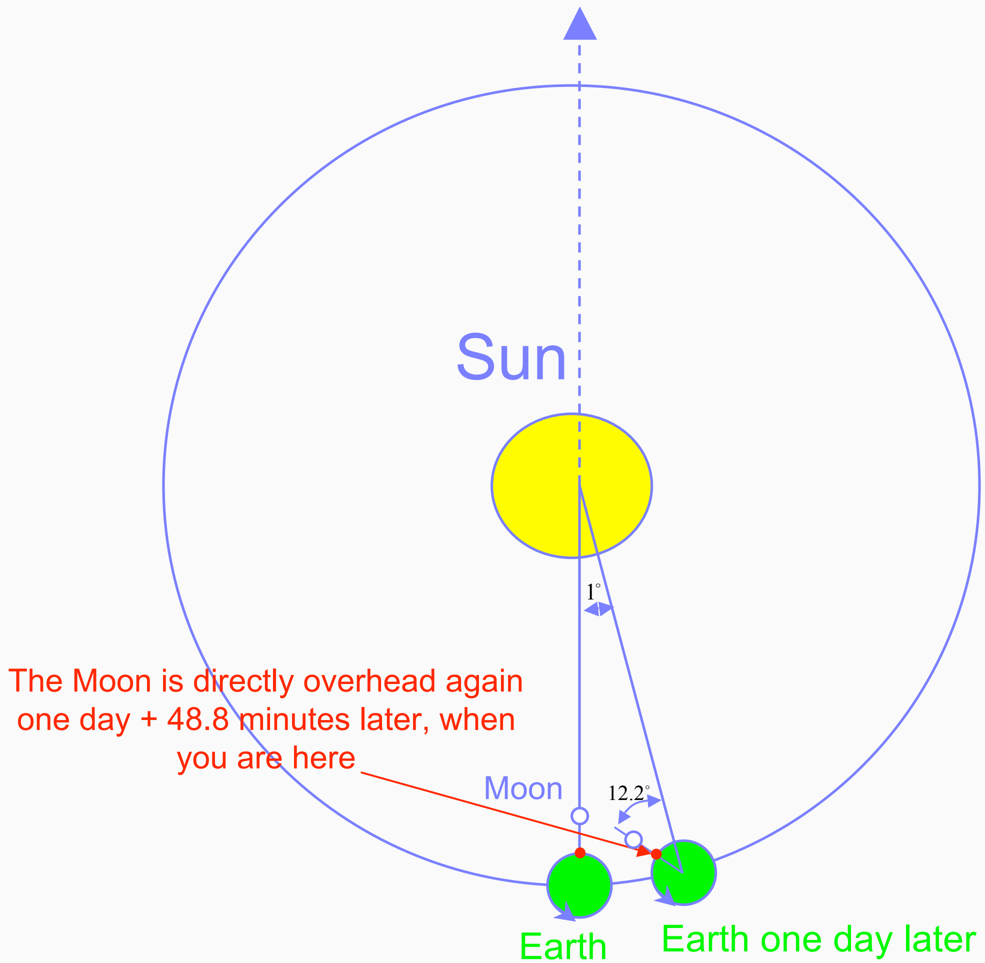
This corresponds to $\frac{360^\circ}{29.5\,days} = \frac{12.2^\circ}{day}$.

$\rightarrow \left(\frac{12.2^\circ}{day}\right)\left(\frac{24\,hours}{360^\circ}\right)\left(\frac{60\min}{hour}\right) = 48.8\min$

So the Moon rises ~ 48.8 minutes later each day.

NOTE! The angles are greatly exaggerated

The moon rises ~50 min later each day



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So the Moon rises ~ 48.8 minutes later each day.

NOTE! The angles are greatly exaggerated

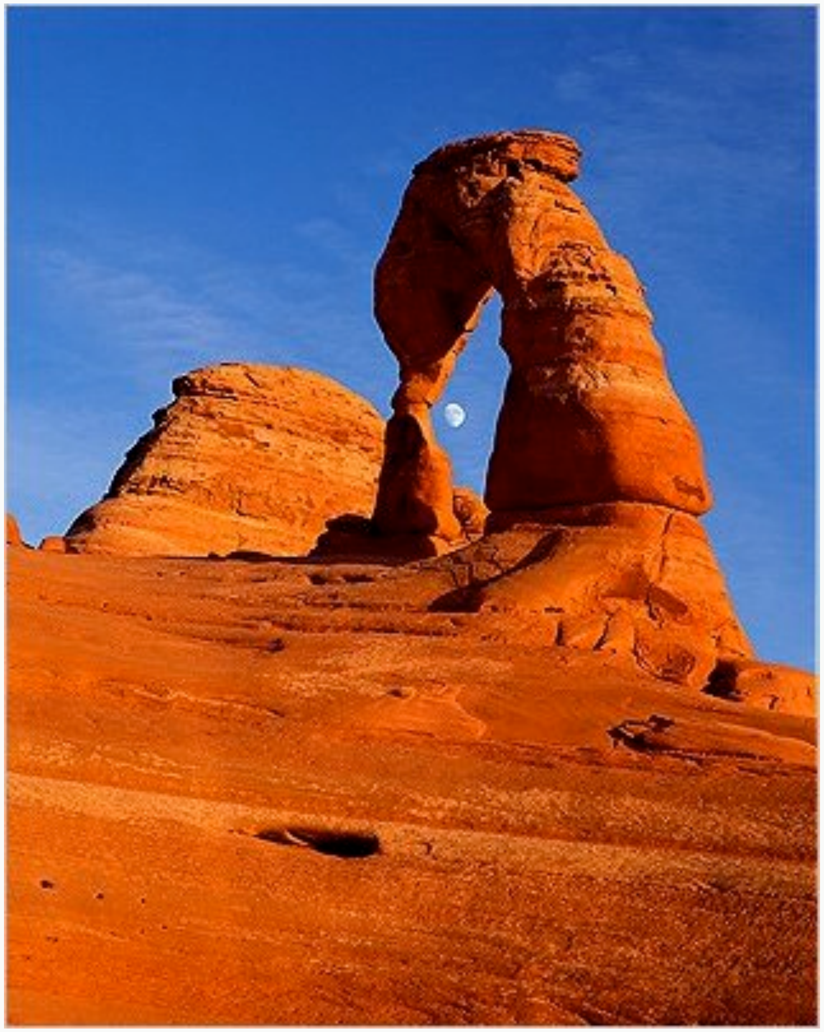
Moon & month

- The approximately 4 weeks it takes the Moon to complete one orbit inspired the concept of our month

- Month lengths formerly followed motions of the moon. But our calendar's irregular distribution of days in the various months no longer corresponds to either the lunar cycle or to that of any other object in the heavens.

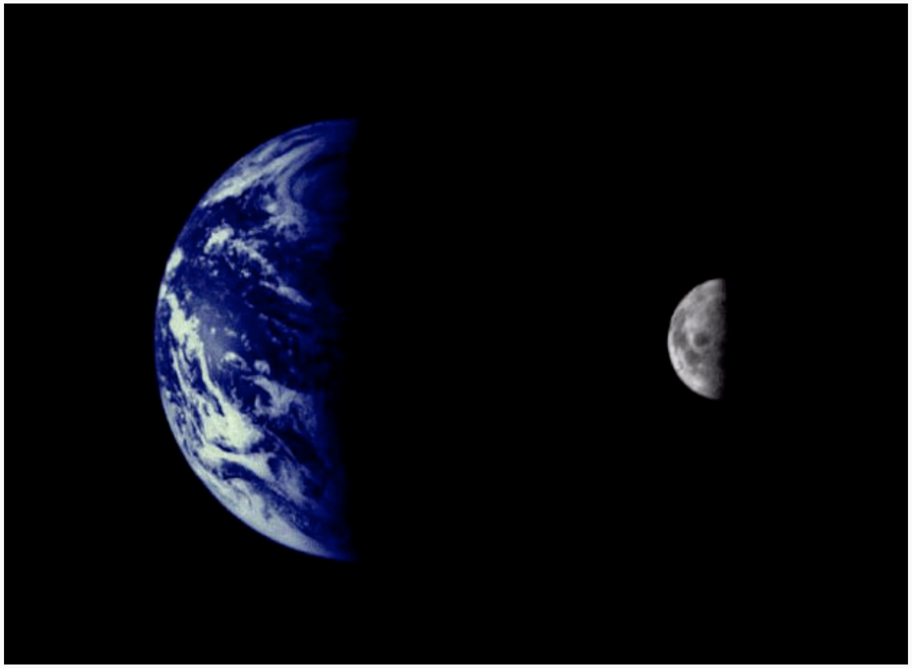
Time of moonrise

- The moon rises about 50 minutes later each day than the day before.



Phases of the Moon

- Like the Earth, the Moon is a sphere which is *always half illuminated by the Sun*, but as the Moon orbits the Earth *we get to see more or less of the illuminated half.*



Phases of the Moon

- This image was taken by NEAR as it flew by the Earth-Moon system in January 1998.

Phases of the Moon

- As the Moon orbits the Earth *we get to see more or less of the illuminated half.*

Phases of the Moon

Waxing crescent

First quarter

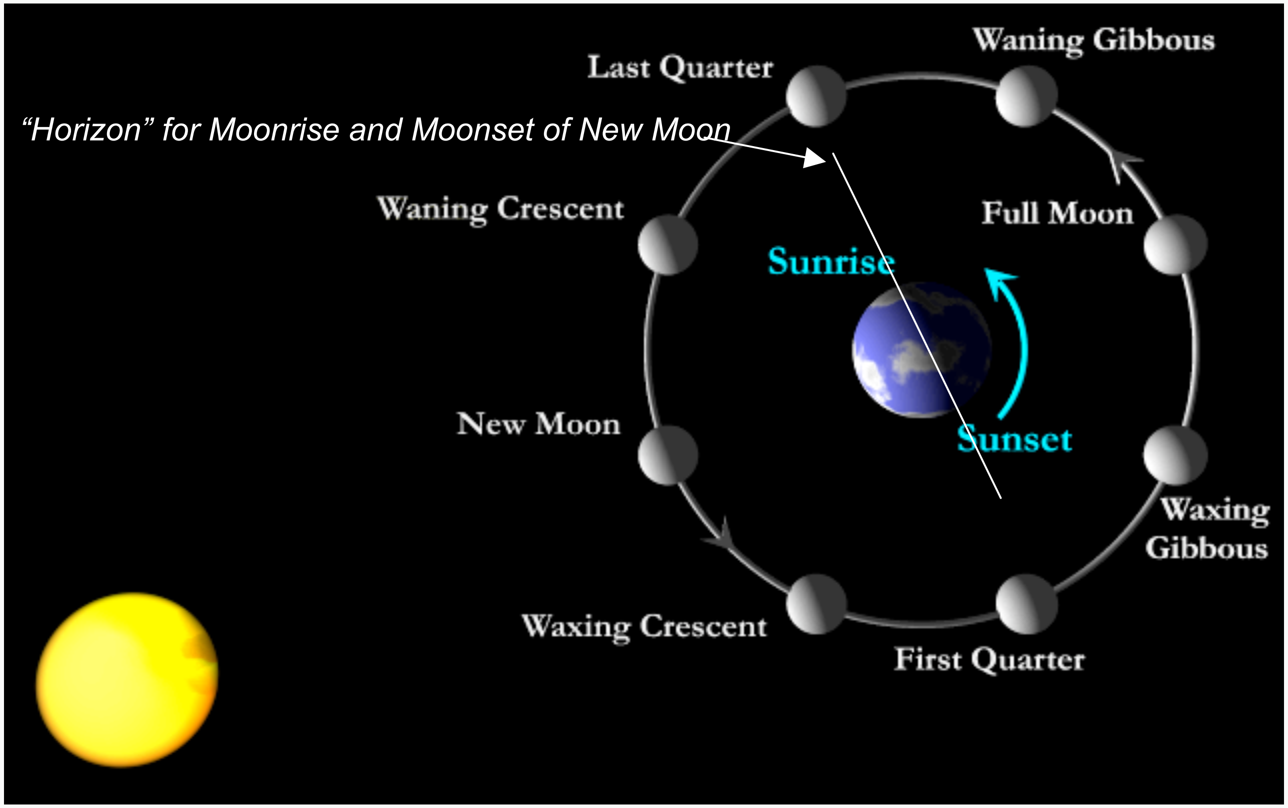
Waxing gibbous

Waning gibbous

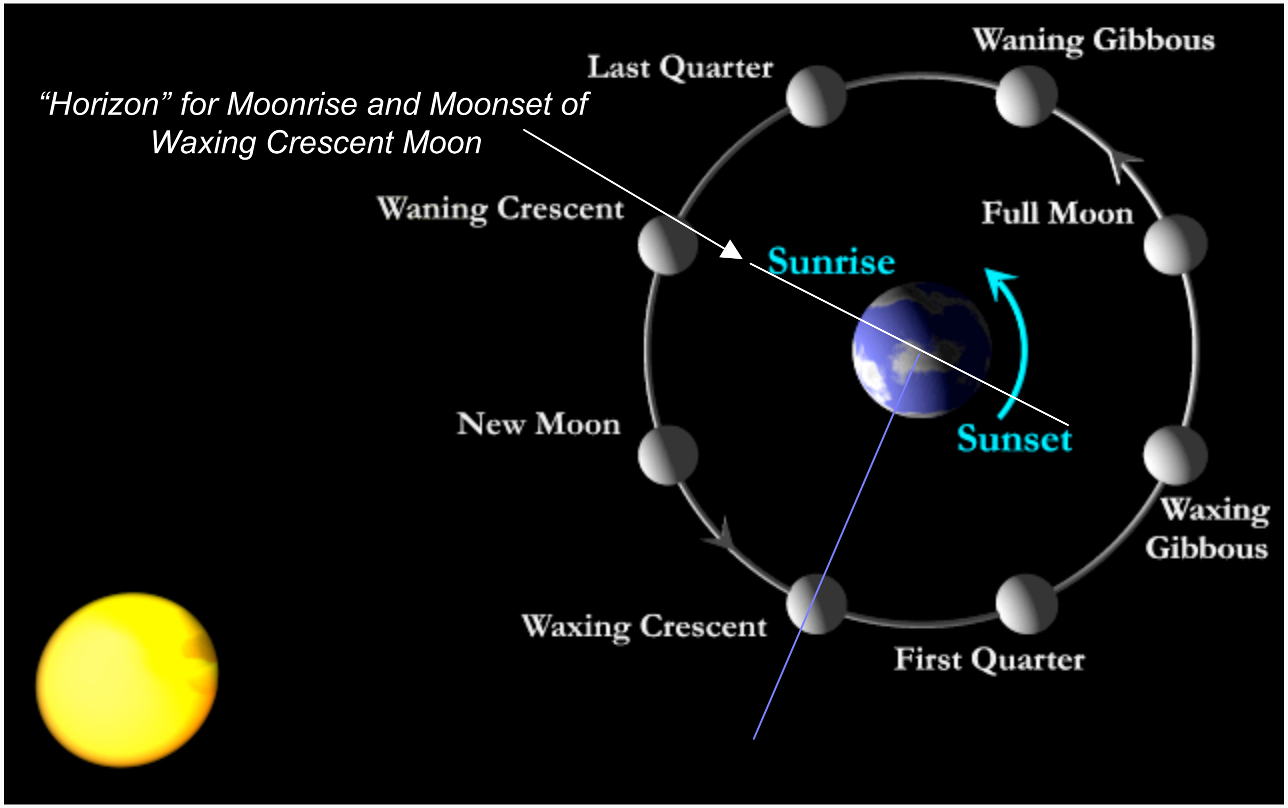
Third quarter

Waning crescent

Phases of the Moon

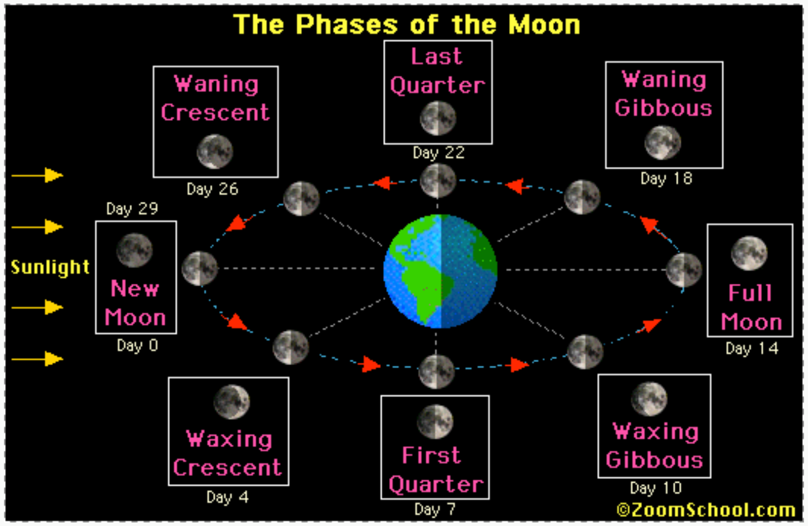


Phases of the Moon



The "age" of the moon

- The time in days counted from the time of new Moon is called the moon's *age*
- The age of the moon is measured in *days.*



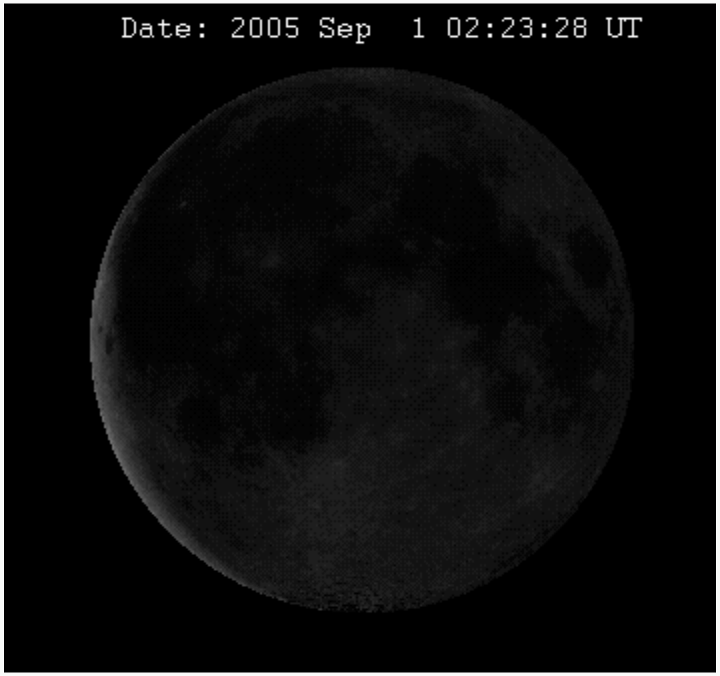
Blue Moon

- Because the cycle of the phases is shorter than most calendar months, the phase of the Moon at the very beginning of the month usually repeats at the very end of the month.

- When there are two full Moons in a month (which occurs, on average, every 2.7 years), the second one is called a "Blue Moon".

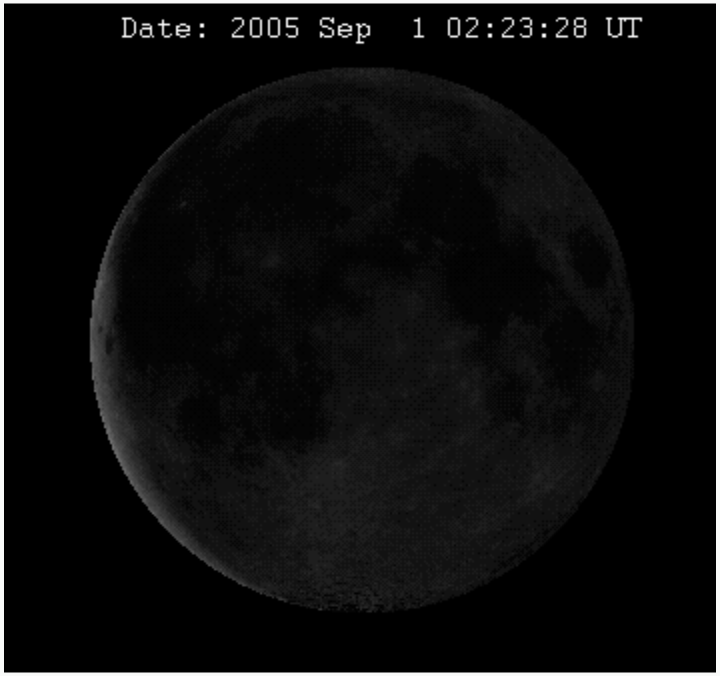
Lunation

- Our Moon's appearance changes nightly. This time-lapse sequence shows what the Moon looks like during a lunation, a complete lunar cycle.



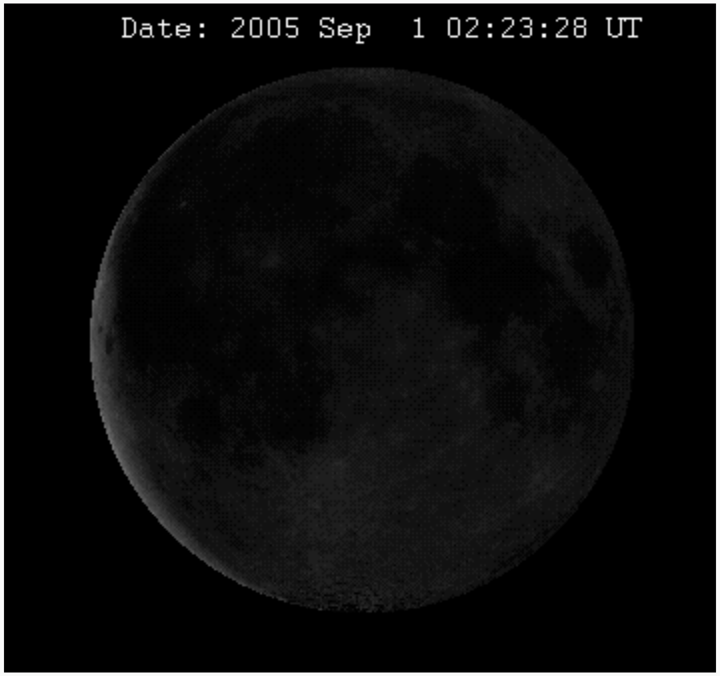
Things that change during a lunation

- The apparent size changes
- The phase changes
- We can see a different area (not always the same 50%)



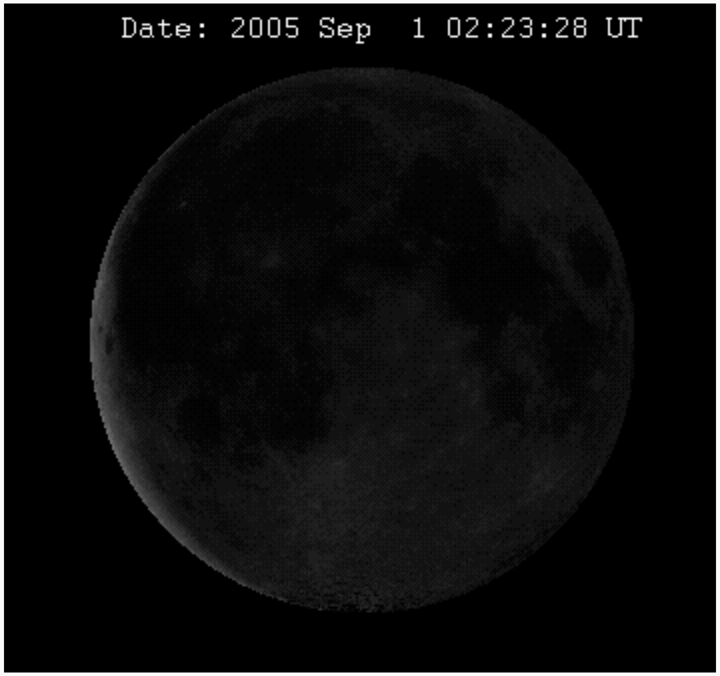
Apparent size of the Moon changes

- Due to the elliptical shape of the Moon's orbit, the apparent size of the Moon's disk changes as its distance from Earth varies



Apparent size of the Moon changes

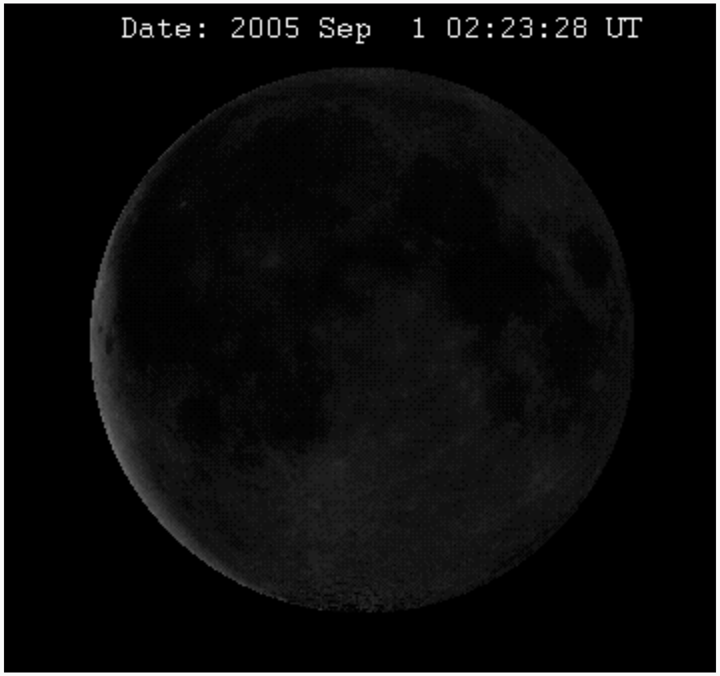
- Note that the closest and farthest points do not always occur at the same phases



59% of the Moon's surface is observable from Earth

- Although the Moon's rotation on its axis is synchronously locked with its revolution around Earth, *librations* permit a terrestrial observer to see slightly differing halves of the Moon's surface at different times.

- This means that a total of, not 50%, but 59% of the Moon's surface can be observed from Earth.



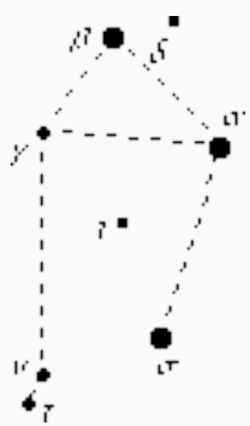
Libration

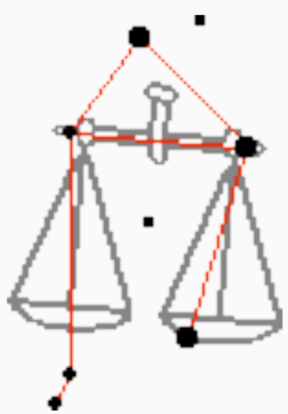
- A *libration* (from the Latin verb *libro -are* "to balance, to sway", cf. *libra* "scales") is a very slow oscillation, real or apparent, of a satellite as viewed from the larger celestial body around which it revolves.

- The term usually refers to the apparent movements of the Moon relative to Earth, which can be compared to the rocking of a pair of scales about the point of balance.

- Note same origin as that of the constellation Libra

The Constellation Libra





3 types of libration

- *Libration in latitude* is a consequence of the Moon's axis of rotation being slightly inclined to the normal to the plane of its orbit around Earth. Its origin is analogous to the way in which the seasons arise from Earth's revolution about the Sun.

- *Libration in longitude* is a consequence of the Moon's orbit around Earth being somewhat eccentric, so that the Moon's rotation sometimes leads and sometimes lags its orbital position.

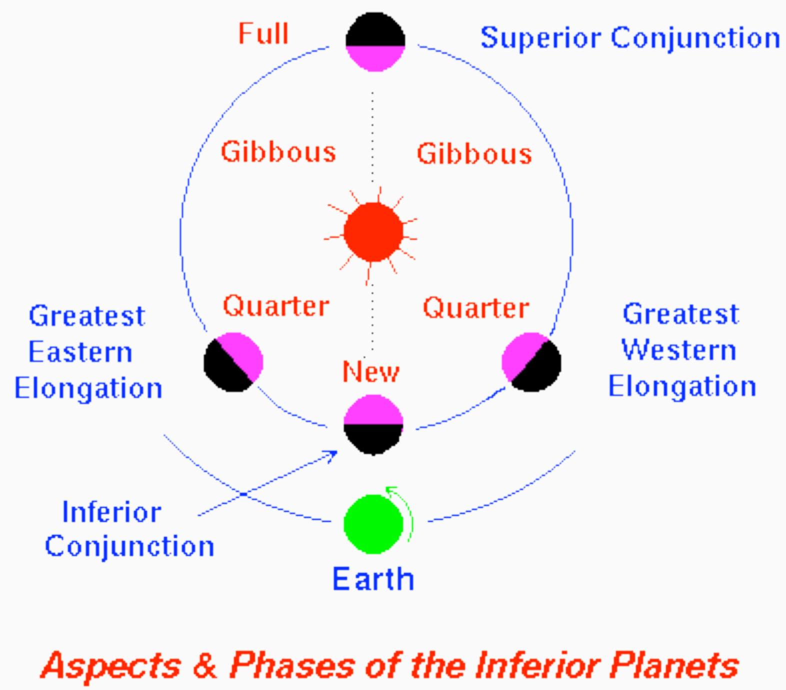
- *Diurnal libration*. This is a consequence of Earth's rotation. This carries an observer first to one side and then to the other of the straight line joining Earth's center to the Moon's center, allowing the observer to look first around one side of the Moon and then around the other.

Planets have phases, too

- Voyager 2 spacecraft camera captured Neptune and Triton together in crescent phase in 1989.

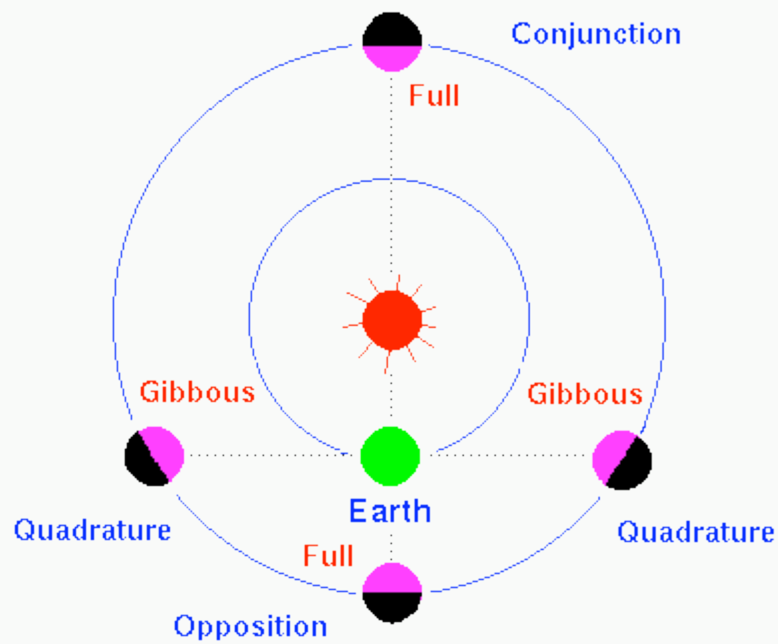
Planets have phases, too

- The inferior planets exhibit a complete set of phases (just like the Moon) as viewed from the Earth



Planets have phases, too

- The superior planets do not exhibit a full range of phases
- They are always gibbous or full

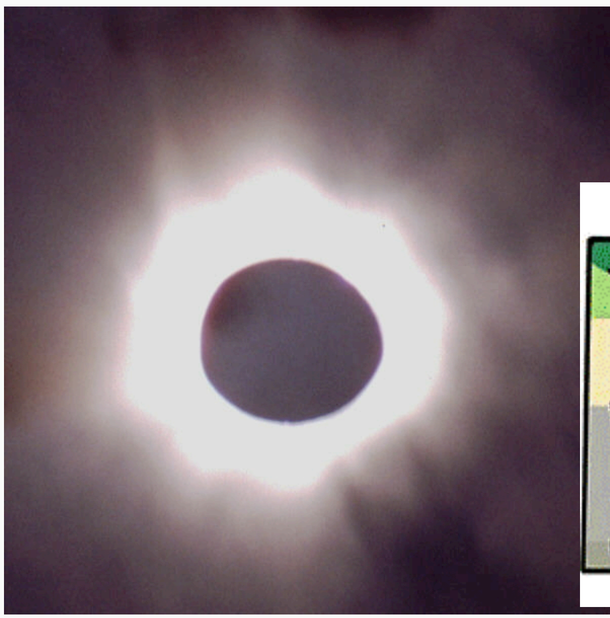


Aspects & Phases of the Superior Planets

Chapter 1
Discovering the Night Sky

- Scales of the Universe
- Patterns of Stars
- Earthly cycles
- *Eclipses*

Eclipses




Frank and Ernest
NEWS
ECLIPSE OF SUN DUE
THERE'S GOING TO BE A SOLAR ECLIPSE!
THE ORIGINAL ROLLING BLACKOUT!
6-14
THAVES
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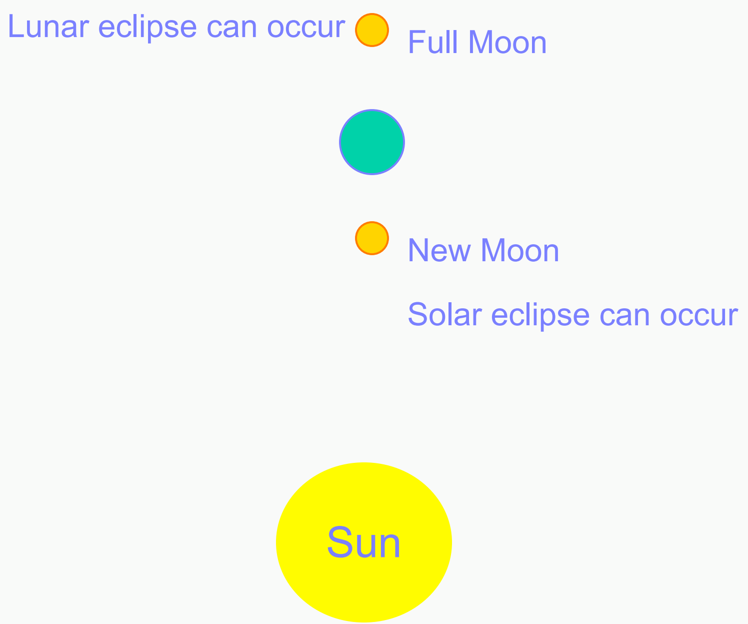
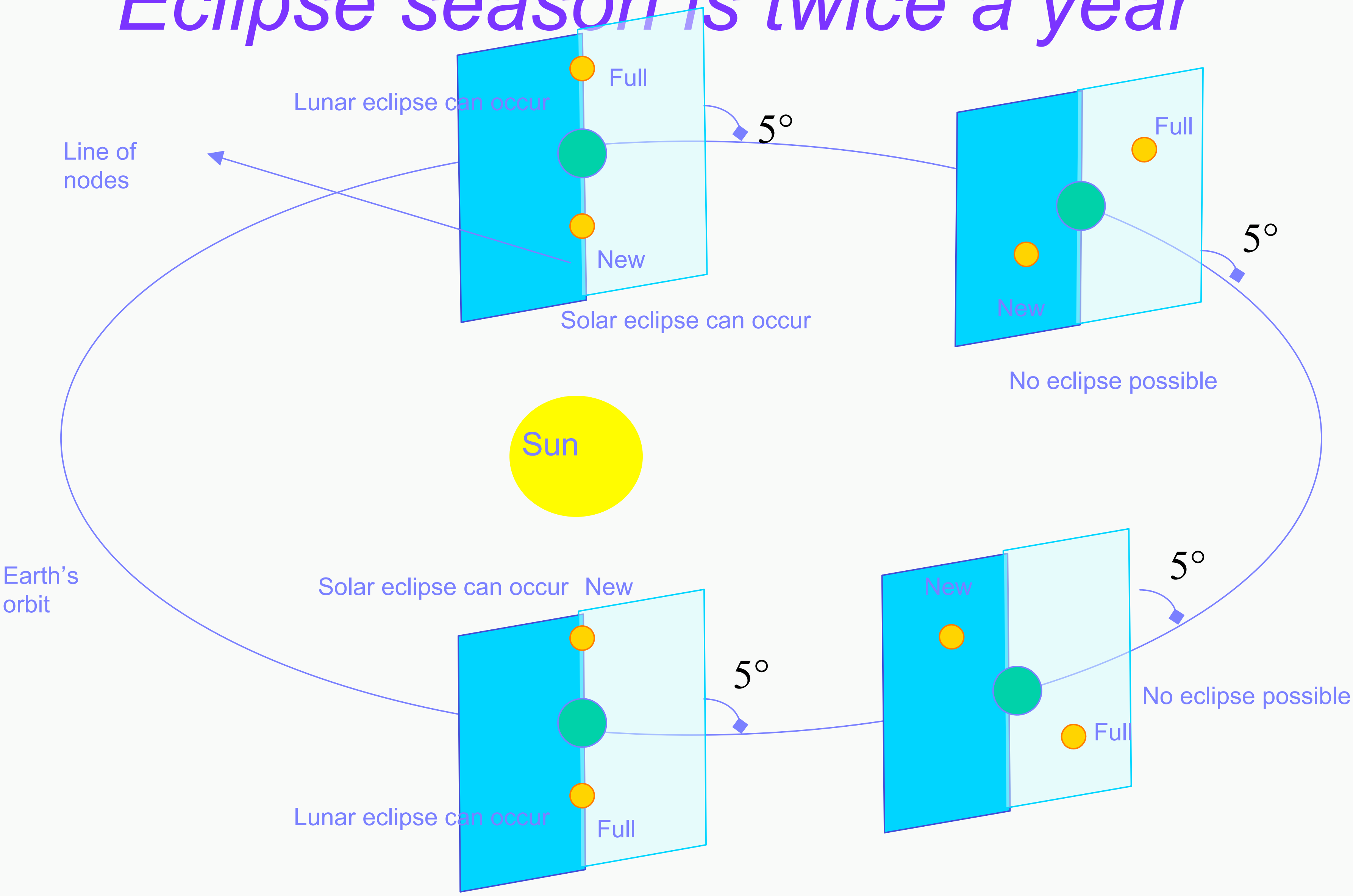
How Eclipses Work

- The Moon or Earth can block the sun.



- But eclipses cannot happen every full or new Moon
- The Moon’s orbit is not in the same plane as the Sun; it is tilted 5 degrees out of the ecliptic
- Eclipse season is twice a year.

Eclipse season is twice a year



Kinds of Eclipses

- *Solar Eclipse*

  Moon’s shadow on the earth

  Only occurs at a new moon.

- *Lunar Eclipse*

  Earth’s shadow on the moon.

  Only occurs at a full moon.

Kinds of Eclipses

- *Solar Eclipse*

  Partial - crescent sun remains

  Total - all of the sun is blocked

  Annular - a ring of the sun remains

- *Lunar Eclipse*

  Partial - moon is partially dark

  Total - moon is dark red or copper-colored (explained in a few slides)

  Earth’s atmosphere passes some light.

Kinds of Eclipses

- *Solar Eclipse*

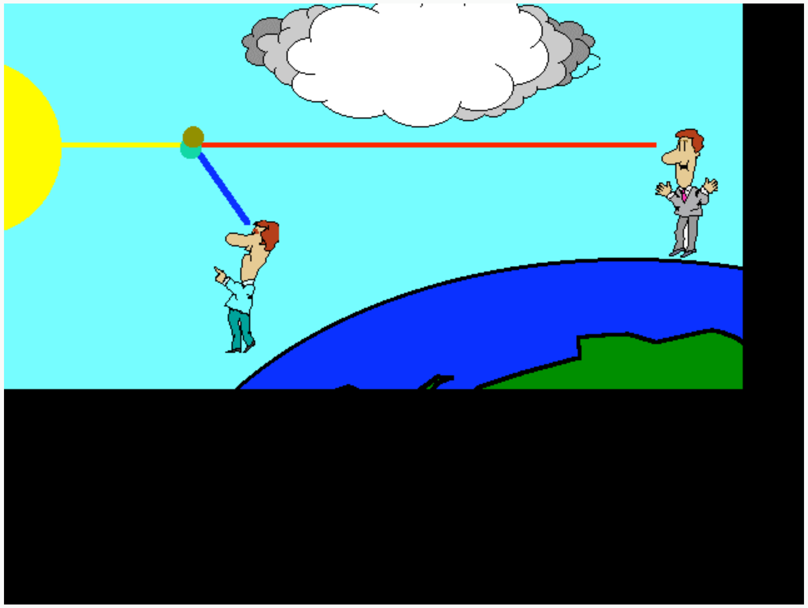
  Maximum duration of totality:
  7.5 minutes

- *Lunar Eclipse*

  Maximum duration:
  1 hour 47 minutes

Why is the sky blue and the sunset red?

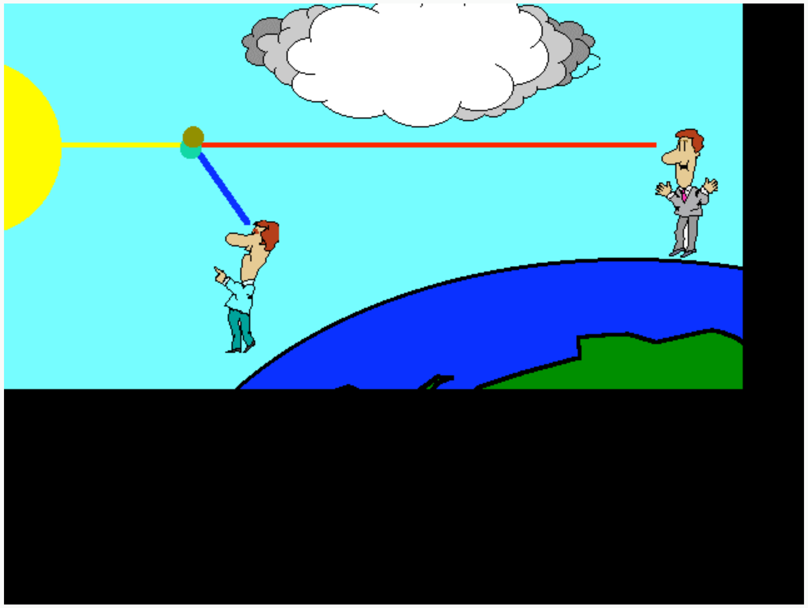
- A clear, cloudless day-time sky is blue, because molecules in the air scatter blue light from the sun more than they scatter red light.
- This scattering is called Rayleigh scattering and is proportional to $1/\lambda^4$
- So it is a 10 times larger effect for blue (300 nm) than for red (700 nm) light



Why is the sky blue and the sunset red?

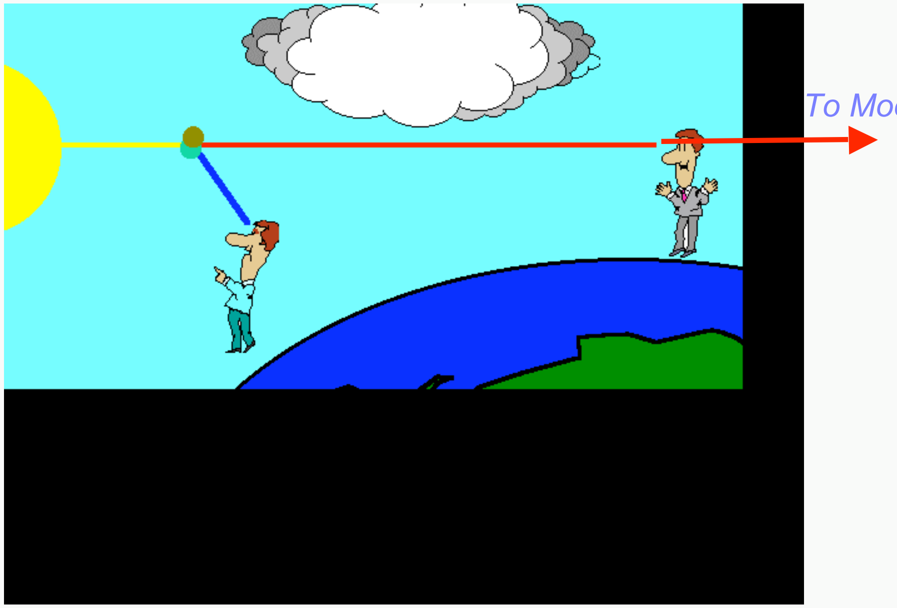
- When we look towards the sun at sunset, the light must travel through much more atmosphere than when the sun is more directly overhead

- So we see red and orange colors, because more of the blue light has been scattered out and away from the line of sight



Why does the Moon appear reddish during lunar eclipse?

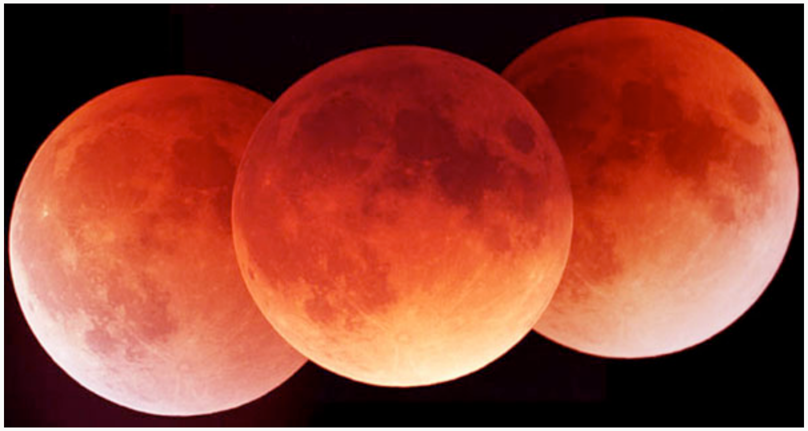
- During a lunar eclipse, this red light is refracted by the Earth's atmosphere and can reflect off the Moon.
- This makes the Moon look reddish



Why does the Moon appear reddish during lunar eclipse?

- The red tint of the eclipsed Moon is created by sunlight first passing through the Earth's atmosphere, which preferentially scatters blue light (making the sky blue) but passes and refracts red light, before reflecting back off the Moon.

- Differing amounts of clouds and volcanic dust in the Earth's atmosphere make each lunar eclipse appear differently.



Why does the Moon appear reddish during lunar eclipse?

- Before and after totality, can see some sunlight reflected off the moon
- During totality, no direct sunlight hits the moon, only the red light refracted through the earth's atmosphere

Viewing Eclipses

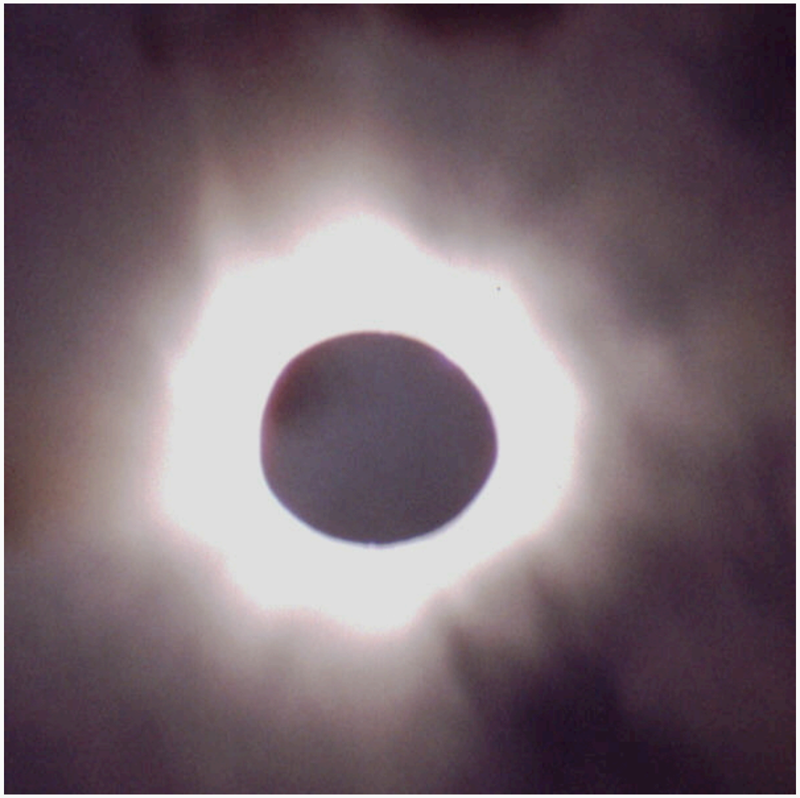
- Never look directly at the sun, even at a partial eclipse
- View sun through #14 welder's glass or special mylar filters.
- It's ok to look at lunar eclipses

Eclipse Prediction

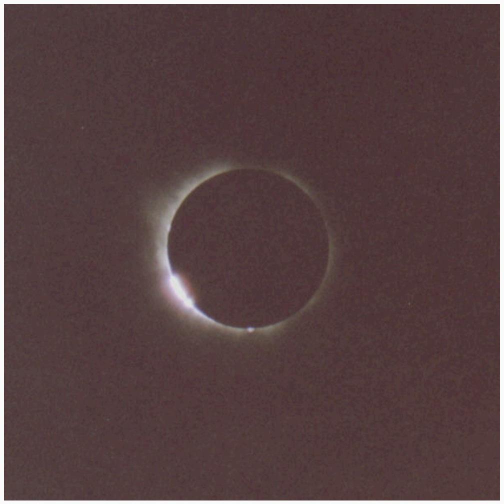
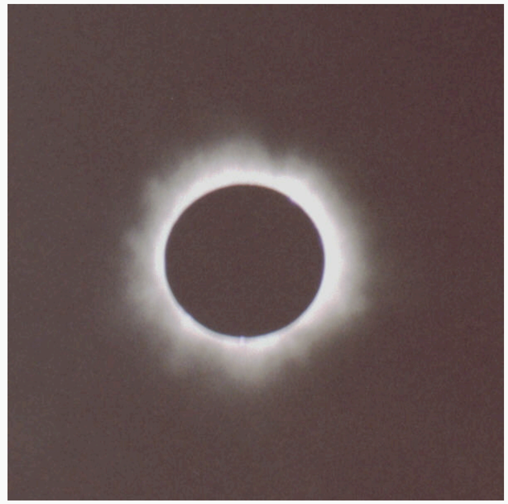
- The cycles of the sun and moon cause eclipses in a predictable pattern.
- The same eclipse occurs every 18 years - the *saros* cycle.
- Last total solar eclipse was December 4, 2002 in Africa, Indian Ocean and Australia.
- Next partial solar eclipse in DeKalb is March 19, 2007.
- Next total solar eclipse in the US is August 21, 2017.

Science during eclipses

- Eclipses are fun
- Eclipses also provide a golden opportunity to learn more about the sun.
- The hot gases surrounding the Sun can be observed, providing information about its
  - temperature
  - chemistry
  - atmospheric activity.

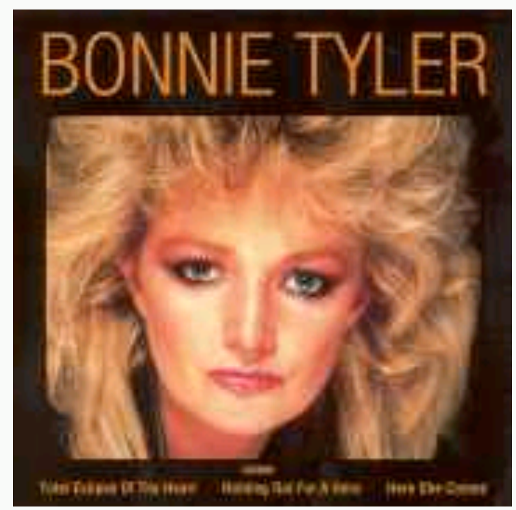


Total Eclipse of the Sun

Total Eclipse of the Heart

Bonnie Tyler



http://www.eso.org/outreach/info-events/eclipse99/report-hq.html

Link to video of total eclipse, August 11, 1999, Bavaria, Germany

The duration of totality 2 min 17 sec.